AN INVESTIGATION ON COMPRESSIVE STRENGTH OF SILICA NANOPARTICLE MODIFIED CONCRETE

Prashant
Student, M.Tech Structural engineering
Department of Civil Engineering,
R.N. College of Engg. & Technology, Panipat (India)

Abstract: The present investigation focuses towards the compressive strength of silica nanoparticle modified concrete of M25 grade mix. Four batches were prepared to show the effect of addition of silica nanoparticle on the mechanical behaviour of concrete, through replacing silica nanoparticle by 0.40%, 0.80%, and 1.20% of the weight of cement to compare with the conventional concrete by keeping the water to cement ratio 0.45. The specimens were tested for UPV and compressive strength at ages of 7, 14 & 28 days respectively. On the basis of the experiment results, it was concluded that there is a substantial increase in the early age and small increase in the overall strength of the concrete by increasing the silica nanoparticle content in the concrete mix, when the cement is partially substitute with silica nanoparticle for 7, 14 & 28 days respectively.

Keywords: Concrete, Silica nanoparticle, UPV, Compressive strength, M25 grade

I. INTRODUCTION

In the modern era, concrete is the most common and usable material available on earth which construct a large number of civil infrastructure due to its low cost, fir resistant and able to cast in any desired form. Construction industry is used portland cement as primary binding material. The main environmental issue connected with the production of ordinary portland cement is the emissions of carbon dioxide which is due to the combustion of fossil fuels and calcinations of lime stones. Reduction in the usage of portland cement will reduced the demand of portland cement hence reduction in the emissions of carbon dioxide will occur. Now in present scenario, many researchers try to modify the concrete using subsidiary cementeneous materials, out of which silica nanoparticles is used to reduce the utilities of cement, which will be helpful for both environment and enhancing the strengthening properties of concrete.

Nanoparticles are very small size materials with particle size in nanometers. These particles are very effective in altering and enhancing the strengthening properties of concrete due to its very small size. Too small size of the particles also defines a larger surface area (AlirezaNajiGivi, 2010). As the surface area is depend on the rate of pozzolonic reaction, so a faster reaction can be obtained. Just few percentage of cement is replaced with nanoparticles to get the desired outcome. When these nanoparticles added in concrete, it fills up the void and the pores of the microstructure and hence enhancing strength is obtained. If small amount of silica nanoparticles are used in concrete mix has enhancing the strength properties of concrete. When Silica nanoparticles mixed in the cement in the presence of water can produce C-S-H with nano size. These nano-crystals are suitable for filling up the micro pores of concrete, and hence enhancing the permeability and strength of concrete.

II. LITERATURE REVIEW

Kavitha and Sandhiyadevi (2016) investigated the effect of NS on the mechanical and durability and flexural properties of concrete. From the present investigation the performance of nanosilica concrete with and without flyash was studied and they were compared to the performance of control mix. Fresh properties of the concrete were determined by carrying out the workability test, compacting factor, veebee, and flow test. The mechanical properties are determined by split tensile strength, compressive strength, modulus of elasticity, impact resistance and flexural strength. The durability properties are determined by acid attack test, sulphate attack test, bulk diffusion test. The behavior of nanosilica beam under flexure was also studied by 2 point loading flexure test.

DariushHajizadehAsl (2016) said that concrete is the world's largest adopted building material in several civil engineering applications and therefore, any attempt to increase efficiency regarding the process of its production can lead to a high level of economic benefit. The most important challenge in using concrete is to improve its mechanical properties as well as its durability in different applications. Nano-silica has gained a lot of attention as an additive agent to the cement for production concrete due to its improving influence on mechanical properties and durability of the concretes. The present review summarized part of studies on the effect of NS on concrete; however, it seems that there should be more research to find out other effect of Nanosilica in concretes and proper dosage for various applications in different environments.

Nihat and Layth (2017) studied on the influence of NS on the durability, gas permeability and mechanical characteristics of HSLWC. In order to find out the impact of NS on the properties of concrete, LWA is fabricated with cold bonded method with process of pelletization by mixing 10% cement with 90% FA. After that the utilization of HSLWC is completed by partial replacement of normal coarse aggregate in a level, i.e. (0 to 40% in a multiple of 10%) without and with NS at constant water/cement ratio 0.35 and constant at ratio of 20% FA. The concrete is examined at a age of 28 & 90 days for splitting tensile strength, gas permeability, sorptivity index. Analysis revealed that the increase in the substitution of LWC aggregate affecting the strength & permeability properties negatively. On the other side, the outcomes explained that 3% nanosilica addition to HSLWC reduce the negative characteristics of LWC aggregate and tends to remarkable increase in mechanical properties also the gas permeability and sorptivity values are decreased upto 40% and 25% respectively, if the values are compared with the previous substution levels of LWA. However, NS particles have better results on conventional concrete compared to the LWC.

Reddy and Meena (2018) Experimental investigated the utili-zation of FA and Alccofine contributes for the achievement of high strength TBC. It was observed that all TBC mixes with all four grades of NS sets quickly and also achieved high strength when compared with other blended mixes. The increase in com-pressive strength is about 20.699%, 18.3050% and 10.8796% for CN4 mix at 7, 14 and 28 days respectively when compared to CM. it was also found that when the XTXla NS percentage was in-creased to 2%, 3% as additive compressive strength reduced con-siderably. The total substitution of cement by 25% (FA 15% and ALC 10%) brings about reduction in cost resulting in economy. Furthermore the reduction in cement leads to sustainability, since there is reduction in CO2 emission in cement manufacture.

Reddy, Meena, Priyanka and Mounika (2019) analysed that the concrete having addition of FA and NS sets quickly when compared to conventional concrete. Compressive strength test result with FA and NS combination at different ages revealed that the outcomes are superior compared to conventional concrete. In this investigation, the maximum compression strength was developed with the addition of FA & XTXla type NS at 25-1% respectively, it also show highest strength values in split tensile and flexural strength. Addition of substitute materials leads to ecofriendly and sustainable concrete reduce the overall manufacturing cost of the concrete.

III. EXPERIMENTAL WORK

MATERIAL USED FOR TEST:-

The materials used to design the concrete mix M25 grade are cement, sand (fine aggregate), coarse aggregate, water and silica nanoparticle.

(A)Cement:-For the preparation of samples shree jang rodhak OPC of 43 grade conforming to IS: 269-2015 is taken.

Properties of ordinary portland cement

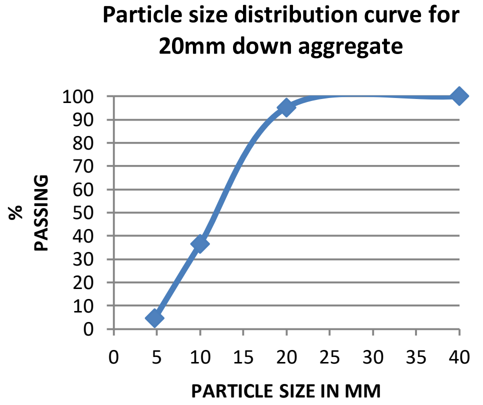
Physical Properties	Requirements	Results
Grade	43MPa	----
Specific gravity	3.15 kg/m^3	----
Initial setting time	Min. 30 min	134 min
Final setting time	Max. 600 min	248 min
Fineness (90 micron sieve)	<10% residue by weight	1.39 %
Consistency	----	26.5 %
C.S. at 3 days	Min. 23Mpa	32.5 Mpa
At 7 days	Min. 33Mpa	44 Mpa
At 28 days	Min. 43Mpa	51.5 Mpa

(B)Fine and Coarse aggregate:-Sand as fine aggregates and coarse aggregates are bought from local building material supplier and the sieve analysis of the samples are done. It is observed that the sand (fine aggregate) and coarse aggregate collected is fulfilling the requirement of IS 383-1970.The physical properties of both fine aggregate and coarse aggregate are evaluated as per IS: 2386 (Part III)-1963.

Sieve analysis of 20mm down coarse aggregate

Total weight taken = 5000 grams

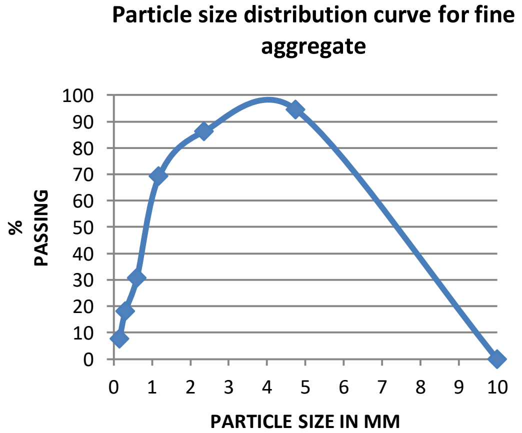
S.No.	W. Retained	C.W. Retained	% C.W.	% Pass	Req.
40 mm	0	0	0	100	100
20 mm	238	238	4.8	95.2	95-100
10 mm	2937	3175	63.5	36.5	25-55
4.75 mm	1595	4770	95.4	4.6	0-10
Pan	230	5000	100	0	---



Sieve analysis of fine aggregate

Total weight taken = 1000 grams

S.No.	W. Retained	C.W. Retained	% C.W.	% Pass.	Req.
10 mm	0	0	0	100	100
4.75 mm	55	55	5.5	94.5	95-100
2.36 mm	82	137	13.7	86.3	60-65
1.18 mm	171	308	30.8	69.2	30-70
600 mic	386	694	69.4	30.6	15-34
300 mic	126	818	81.8	18.2	5-20
150 mic	105	923	92.3	7.7	0-10
Pan	77	1000	100	0	---



Properties of coarse aggregate and fine aggregate

Property	Coarse Aggregate	Fine Aggregate
Specific Gravity	2.721	2.66
Bulk Density (kg/L)	1.410	-
Loose Bulk Density (kg/L)	1.245	-
Water Absorption (%)	0.97	1.52
Impact Value	27.01	-
Crushing Value	26.591	-
Fineness Modulus	3.38	2.84

(C)Water:- Raw water was used in this investigation. The test results of raw water carried out in the laboratory for impurities. Specific gravity is taken as 1.00.

Test result for impurities in water used for curing and mixing

Test	Test method	Results	Limits
Organic	IS 3025(P-18)-1984	162	Max. 200, mg/l
Inorganic	IS 3025(P-18)-1984	711	Max. 3000, mg/l
Sulphates	IS 3025(P-24)-1986	182.1	Max. 400, mg/l
Chlorides	IS 3025(P-32)-1988	201.2	Max. 2000 for PCC, Max. 500 for RCC, mg/l
Suspended matter	IS 3025(P-17)-1984	39	Max. 2000, mg/l
P_H	IS 3025(P-11)-1983	6.89	Min. 6

(D)Silica nanoparticle:- Silica nanoparticle used for the replacement of cement was bought from a local supplier.

Physical property data used in this research was also provided by the supplier.

Properties of silica nanoparticle

Test	Std. Requirement	Result
SPECIFIC SURFACE AREA(m^2/g)	200±20	204
PH VALUE	3.7-4.5	4.23
LOSS ON DRYING @ 105 DEG.C (5)	≤ 1.5	0.49
LOSS ON IGNITION @ 1000 DEG.C (%)	≤ 2.0	0.67
SIEVE RESIDUE (5)	≤ 0.04	0.02
TAMPED DENSITY (g/L)	40-60	48
SiO2 CONTENT (%)	≥ 99.8	99.89
CARBON CONTENT (%)	≤ 0.15	0.06
CHLORIDE CONTENT (%)	≤ 0.0202	0.009
Al2O3	≤ 0.03	0.005
TiO2	≤ 0.02	0.004
Fe2O3	≤ 0.003	0.001

Mix proportion for M25 grade concrete mix obtained is 1: 1.452: 3.015 with water to cement ratio 0.45

Batch no.	A	B	C	D	Total
Material	Ctrl. (kg)	SNP in kg b.w.c			material Req. (kg)
		0.40%	0.80%	1.20%	
SNP	----	0.059	0.119	0.178	0.356
Cement	14.868	14.809	14.749	14.690	59.116
Fine agg.	14.25	14.250	14.250	14.250	57
Coarse agg.	21.583	21.583	21.583	21.583	86.332
Water	6.696	6.696	6.696	6.696	26.784

Above Table showing material required for the preparation of specimen

PREPRATION OF SPECIMEN FOR UPV AND COMPRESSIVE STRENGTH TEST:

For conducting compression strength and ultrasonic pulse velocity test on concrete, cubes of size 150mmX150mmX150mm are casted. For better compaction, rotator mixture is used for mixing and a mechanical vibrator is used. After successful casting of concrete cubes, these are de-moulded after 24 hours & immersed in water for 7, 14 & 28 days maintaining 27^0C.

UPV TEST REULTS:-

UPV test performed on specimens were carried out according to the guidelines provided by IS 13311(Part 1):1992 at 7, 14 & 28 days using ultrasonic pulse velocity apparatus. Results of the UPV test are discussed below.

UPV Test Result for Control Specimen

S.No.	No. of Days Curing	Specimen No.	UPV (M/Sec)	Time ((μs)
1	7	A1	4685	32.0
		A2	4777	31.4
		A3	4791	31.1
2	14	A4	4571	32.2
		A5	4601	30.6
		A6	4626	31.4
3	28	A7	4815	31.1
		A8	4847	30.9
		A9	4768	31.4

UPV Test Result for Specimen with silica nanoparticle 0.40% b.w.c.

S.No.	No. of Days Curing	Specimen No.	UPV (M/Sec)	Time ((μs)
1	7	B1	4490	33.4
		B2	4386	34.2
		B3	4388	34.1
2	14	B4	4441	33.8
		B5	4631	32.4
		B6	4495	33.4
3	28	B7	4676	32.0
		B8	4732	31.7
		B9	4859	30.8

UPV Test Result for Specimen with silica nanoparticle 0.80% b.w.c.

S.No.	No. of Days Curing	Specimen No.	UPV (M/Sec)	Time ((μs)
1	7	C1	4630	32.4
		C2	4629	32.4
		C3	4702	31.9
		C4	4739	31.7
		C5	4633	32.4

2	14	C6	4670	32.1
3	28	C7	4702	31.9
		C8	4783	31.3
		C9	4770	31.4

UPV Test Result for Control Specimen with silica nanoparticle 1.20% b.w.c.

S.No.	No. of Days Curing	Specimen No.	UPV (M/Sec)	Time ((μs)
1	7	D1	4499	33.3
		D2	4261	35.2
		D3	4564	32.8
2	14	D4	4621	32.5
		D5	4705	31.9
		D6	4661	32.2
3	28	D7	4672	32.1
		D8	4712	31.8
		D9	4808	31.2

Fig. shows UPV Test apparatus and concrete specimen

Fig. shows UPV Test performed on concrete specimen

COMPRESSIVE STRENGTH TEST REULTS:-

Compressive strength test performed on specimens were carried out according to the guidelines provided by IS: 516-1959 at 7, 14 & 28 days using CTM by keeping application of load 140 kg/cm^2 till material fails under surface dry condition. Three samples are examined for appropriate mix category and the mean compressive strength of 3 samples is recorded as the compressive strength of the specified category. Results of the compression test are discussed next.

C.S. Test Result for Control Specimen

S. No.	Curing days	Specimen No.	Load (KN)	C.S. (MPa)	A.C.S. (MPa)
1	7	A1	510	26.67	24.49
		A2	545	24.22	
		A3	598	26.58	
2	14	A4	690	30.67	30.68
		A5	705	31.33	
		A6	676	30.04	
3	28	A7	824	36.62	35.85
		A8	818	36.36	
		A9	778	34.58	

C.S. Test Result for Specimen with silica nanoparticle 0.40% b.w.c.

S. No.	Curing days	Specimen No.	Load (KN)	C.S. (MPa)	A.C.S. (MPa)
1	7	B1	674	29.96	29.72
		B2	710	31.56	
		B3	622	27.64	
2	14	B4	692	30.76	31.97
		B5	718	31.91	
		B6	748	33.24	
3	28	B7	662	29.42	35.82
		B8	880	39.11	
		B9	876	38.93	

C.S. Test Result for Specimen with silica nanoparticle 0.80% b.w.c.

S. No.	Cured days	Specimen No.	Load (KN)	C.S. (MPa)	A.C.S. (MPa)
1	7	C1	662	29.42	31.58
		C2	720	32	
		C3	750	33.33	
2	14	C4	840	37.33	36.09
		C5	804	35.73	
		C6	792	35.20	
3	28	C7	832	36.98	37.45
		C8	810	36	
		C9	886	39.38	

C.S. Test Result for Specimen with silica nanoparticle 1.20% b.w.c.

S. No.	Cured days	Specimen No.	Load (KN)	C.S. (MPa)	A.C.S. (MPa)
1	7	D1	790	35.11	36.30
		D2	814	36.18	
		D3	846	37.60	
2	14	D4	828	36.8	37.87
		D5	852	37.87	
		D6	876	38.93	
3	28	D7	905	40.22	41.08
		D8	930	41.33	
		D9	938	41.69	

Fig shows Compressive strength Testing Machine

Fig. shows testing of concrete specimen at laboratory

COMPARISON OF COMPRESSIVE STRENGTH TEST RESULTS:-

Comparison of compressive strength for 7 days

7 DAYS RESULTS	STRENGTH (MPa)	INCREASE IN STRENGTH (%)
Control	24.49	----
SNP 0.40% b.w.c.	29.72	21.36
SNP 0.80% b.w.c.	31.58	28.95
SNP 1.20% b.w.c.	36.30	48.22

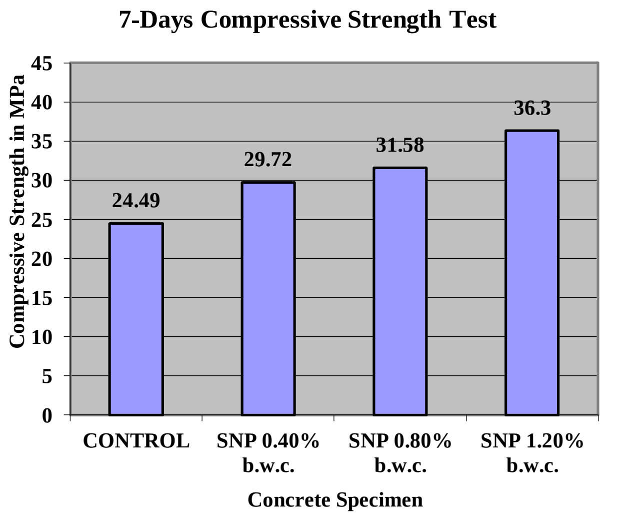


Fig. shows 7 days compressive strength of specimens

Comparison of compressive strength for 14 days

14 DAYS RESULTS	STRENGTH (MPa)	INCREASE IN STRENGTH (%)
Control	30.68	----
SNP 0.40% b.w.c.	31.97	4.20
SNP 0.80% b.w.c.	36.09	17.63
SNP 1.20% b.w.c.	37.87	23.44

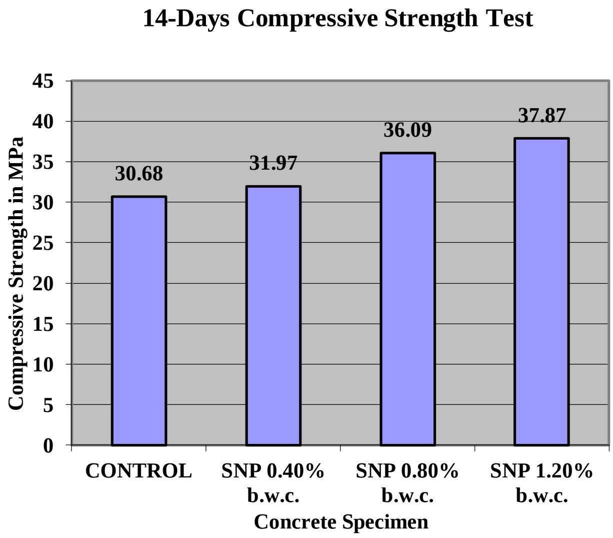


Fig. shows 14 days compressive strength of specimens

Comparison of compressive strength for 28 days.

28 DAYS RESULTS	STRENGTH (MPa)	INCREASE IN STRENGTH (%)
Control	35.85	----
SNP 0.40% b.w.c.	35.82	- 0.08
SNP 0.80% b.w.c.	37.45	4.46
SNP 1.20% b.w.c.	41.08	14.59

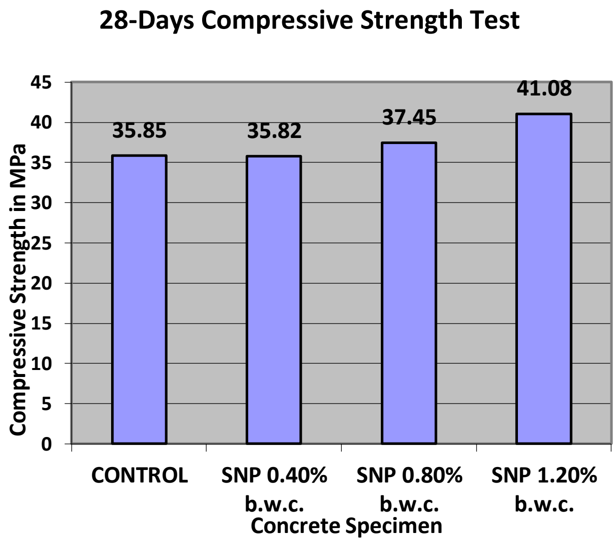


Fig. shows 28 days compressive strength of specimens

COMPARISON OF UPV TEST RESULTS:-

Ultrasonic pulse velocity test results revealed that the quality of the concrete specimen at the age of 28 days is better than that of 7 days and 14 days. Results also expressed the quality of control specimen is better as compared to modified concrete.

IV. CONCLUSION

The conclusions drawn are:

- Enhancement in the compressive strength test result is seen when concrete is modified with certain amount of silica nanoparticle. Compressive strength is maximum for silica nanoparticle 1.20 % b.w.c. & least for silica nanoparticle 0.40 % b.w.c.
- By the modification of concrete with silica nanoparticle there is a substantial increase in the early age strength of concrete compared to the 28 days increase in strength.
- Ultrasonic pulse velocity test results revealed that the quality of modified concrete is slightly affected as compared to control concrete but the overall quality of concrete is good.

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