Effect of nano-silica on properties of blended cement

G.Reddy Babu
Professor, Department of Civil Engineering,
Narasaraopeta Engineering College, Narasaraopet, Guntur-522 601, A.P, India.

ABSTRACT:
The properties of blended cement with nano-SiO_2 (NS) were experimentally studied. The silica, which is the major component of a pozzolan reacts with calcium hydroxide formed from calcium silicates hydration. The rate of pozzolanic reaction is proportional to the amount of surface area available for reaction. Results indicated that setting times were increased with increase in percentage of nano-SiO_2 in cement blended with silica fume. A combination of 6% SF + 3%NS was given the best performance in compressive strength. XRD was used to analyze the results.

***Keywords**: Nano-Silica, Silica fume, Compressive strength, setting time.*

I. INTRODUCTION:

Recently, nano technology has created noticeable scientific interest due to the new prospective uses of particles in nanometer (10^{-9} m) scale. The nano particles can result in radically improved properties from conventional grain size materials of the similar chemical composition. Nano particles are using to design new novel products that function at unique levels. There are few reports on mixing nano particles in cement mortars with materials. Hui Li (1) investigated cement mortars with nano-silica or nano-ferric oxide to explore their super potentials. Ye Qing et al (2) studied influence of nano-silica on properties of hardened cement paste as compared with silica fume. Byung-Wan Jo et al(3) studied characteristics of cement mortar with nano-silica particles Lu and Young (4) produced 800 MPa of compressive strength samples, and Richard and Cheyrezy (5) developed Reactive power Concrete ranging from 200 to 800 MPa. Gengying Li (6) laboratory study carried out on properties of high volume fly ash concrete incorporating nano-SiO_2. With these advantages, the aim of this study is to investigate the influence of nano-SiO_2 on properties of blended cement mortar.

II. MATERIALS AND METHODS

2.1 Material:

Cement: 53-grade ordinary Portland cement conforming to IS: 12269-1987 was used. The physical properties and chemical composition of major compounds of cement are given in Table 1 and 2 respectively.

Table.1 Physical properties of cement

SL No	Property	Result
1	Specific gravity	3.17
2	Fineness	225 m^2/kg
3	Initial setting time	114 minutes
4	Final setting time	224 minutes
5	Compressive strength	MPa
a)	3 days	33
b)	7days	43
c)	28 days	54
6	soundness	0.5 mm

Table. 2 Chemical composition of cement

Sl No	Oxide composition	percent
1	CaO	64.59
2	SiO_2	23.95.
3	Al_2O_3	6.89
4	Fe_2O_3	3.85
5	MgO	0.78
6	SO_3	1.06
7	K_2O	0.46
8	N_2O	0.12
9	Loss on ignition	1.2
10	Insoluble residue	0.35

Sand: Ennore sand conforming to IS: 650-1966 was used. Physical properties are given in Table.3. The cement to fine aggregate ratio was maintained at 1:3(by weight) in the mortar mixes.

Table. 3 Physical properties of sand

Sl No	Property	Result
1	Specific gravity	2.65
2	Bulk density	15.84 kN/m^3
3	Grading	percent
4	Passing 2mm sieve	100%
5	Passing 90µ sieve	100%
6	Particle passing 2mm and retained 1mm	33.33%
7	Particle passing 1mm and retained 500µ	33.33%
8	Particle passing 500µ and retained 90µ	33.33%

Superplasticiser: Commercial superplasticiser was used. Based on a number of trials, 0.8% (by weight of cement) was arrived.

Silica Fume: Silica fume was used in the present investigation. 9% of the cement was replaced by silica fume, where maximum compressive strength was achieved. The chemical composition is given in Table. 4.

Table. 4 Chemical composition of silica fume

Sl No	Oxide composition	Percent
1	CaO	0.5
2	SiO_2	92.3
3	Al_2O_3	2.7
4	Fe_2O_3	1.4
5	MgO	0.3
6	SO_3	0.1
7	K_2O	0.1
8	N_2O	0.1
9	Loss on ignition	1.8

Nano-Silica: Nano-SiO_2 (NS) was used in the present experimental study. Properties provided by manufacturer are given in Table. 5

Table.5 properties of nano-silica

Sl No	Property	Result
	Particle size	15nm
1	SiO_2	➤ 99%
2	Density	$50 kg/m^3$
3	Specific Surface area	$200 m^2/g$

III. METHODS:

The opted percentages of Nano-SiO_2 (NS) were 1, 2, 3, and 4% for this experimental study. The percentages were arrived based on the literature. After number of combinations tried, a combination (91%OPC + 9% SF + 0.8% SP) was fixed for reference specimens where maximum compressive strength was attained. The physical properties of reference specimens are given in Table. 5.

Table: 5 Physical properties of reference cement mortar

Sl No	Property	Result
1	Initial setting time	160 minutes
2	Final setting time	272 minutes
3	Compressive strength	MPa
a)	3 days	49
b)	7 days	59
c)	28 days	67
d)	60 days	75
4	Soundness	0.7 mm

Details of mix proportions for test mortars containing silica fume and nan-SiO_2 are given in Table 6. Four series of specimens were cast for test. The test specimens were cast with (91% OPC + 9% SF + 0.8% SP + NS). Silica fume was replaced with 1, 2, 3 and 4% of Nano-SiO_2(NS) particles for test specimens. The quantities of cement, Ennore sand and mixing waters for each specimen were 200g, 600g and (P/4) + 3 where P denotes the percentage of mixing water required to produce a paste of standard consistence for reference . The obtained water cement ratio for reference was constant for four series of test samples. In four series of test samples, the amount of superplasticizer was arrived in test samples for a constant water to cement ratio of (28%). Initial and final setting times were found out by Vicat's apparatus. Le-Chatelier equipment was used to find soundness of reference and test specimens. The reference and test specimens were prepared using standard metallic cube mould of size 7.06 X 7.06 X 7.06cm for compressive strength of mortar. The blended cement to sand ratio was 1: 3 by weight throughout the tests. The compressive strength of reference and test specimens was studied at different ages, at 3, 7, 28, and 60 days. The compacted specimens in mould were maintained at a controlled temperature of 27 ± 2^0 and 90 percent relative humidity for 24 hours by keeping the moulds under gunny bags wetted by the deioned water and then demolded. After demolding, the specimens were cured in deionised water for 27 days. From the experiments of setting and soundness tests, an average of three values was used to compare the results of the reference specimens. In the case of compressive strength tests, three test specimens were compared with three reference specimens.

Table: 6 Mix proportions of Reference(R) and test (T) samples.

Sample	Mix proportion in percentage				
	cement	SF	NS	W/C ration	SP
R	91	9	0	0.28	0.8
T-1	91	8	1	0.28	1.2
T-2	91	7	2	0.28	1.8
T-3	91	6	3	0.28	2.3
T-4	91	5	4	0.28	2.7

IV. TEST PROCEDURE:

The cement mortars were mixed in a rotary mixer. Nano particles are not dispersing uniformly due to their high surface energy. Accordingly, mixing was performed as follows.

The nano- SiO_2 particles were stirred with the mixing water at high speed (120rpm) for 1minute. The cement and silica fume were added to the mixer and mixed at medium speed (80rpm) for another 30s. Mixing at medium speed, the sand was added gradually. The superplasticizer was added and stirred at high speed for additional 30 s. The mixture was allowed to rest for 90s and then mixed for 1 min at high speed.

V. POWDERED X – RAY DIFFRACTION STUDIES:

Powder X – ray diffraction (XRD) is one of the commonly used techniques for investigation of crystalline compounds in hydrated cement paste (Knudsen, 1976). The reference sample (R) and test sample (T-3) for XRD were ground to a fine powder and a flat specimen was prepared on a glass surface using an adhesive. The diffracted intensities were recorded with powdered diffractometer using monochromatic copper Kα radiation.

VI. RESULT AND DISCUSSION:

6.1 Soundness:

Soundness of reference (R) and test samples (T-1 to T-4) are shown in Fig1. It can be seen that soundness of reference and test samples was same i.e., 0.7 mm. Hence, all samples were considered to be sound.

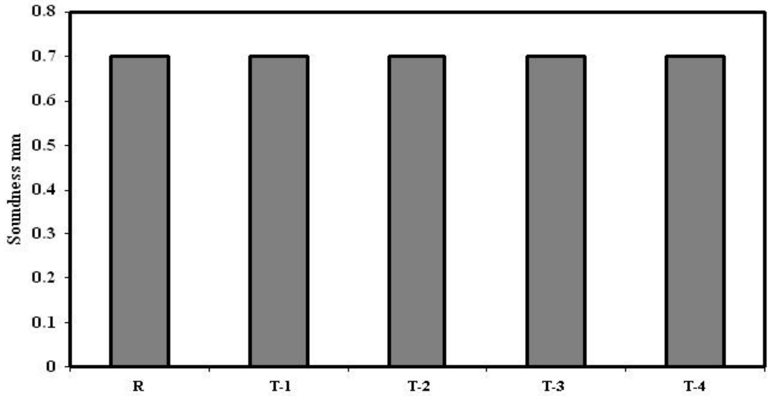

Fig. 1 Influence of nano-silica on soundness of blended cement

6.2 Setting time:

Setting times of reference (R) and test samples (T-1 to T-4) are depicted in Fig 2. It reveals that setting times were increased in test samples compared with reference sample. Increase in initial setting time was 13, 29, 44 and 61 minutes and final setting time was 8, 10, 19 and 28 minutes for T-1, T-2, T-3 and T-4 of test samples compared with that of reference (R) sample. Setting process was increased due increase in percentage of nano-silica. Reason is that, surface area of nano-silica is several times high than the silica fume.

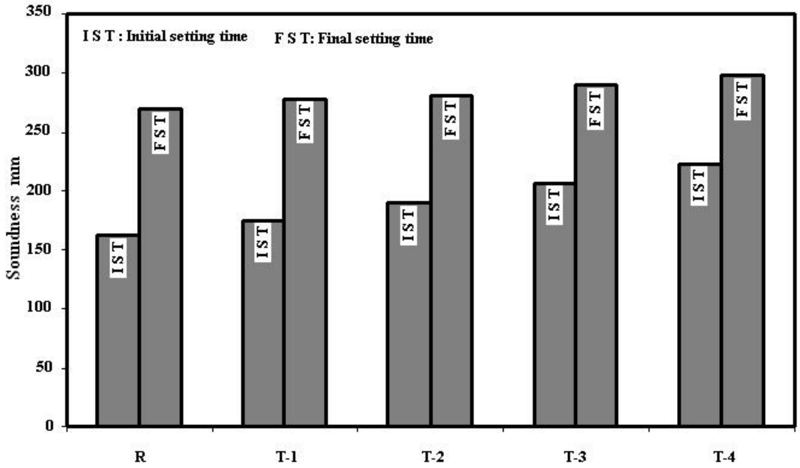

Fig 2 Effect of nano-silica on setting time of blended cement

6.3 Compressive strength:

Influence of nano-silica on compressive strength is shown in Fig 3. It is found that increase in compressive strength was observed with increase in percentage of nano-silica replacing silica fume and age. At early age (3 and 7 days), increase in gain of compressive strength was significant in all test samples compared with reference sample. However, increase in compressive strength was noticed of T-1 to T-3 but decrease in compressive strength had initiated in T-4. As compared with reference, the maximum strength registered in T-3 sample. The strength of test sample T-3 increased by 34.7, 25.4, 19.4 and 17.3% at ages of 3, 7, 28 and 60 days respectively.

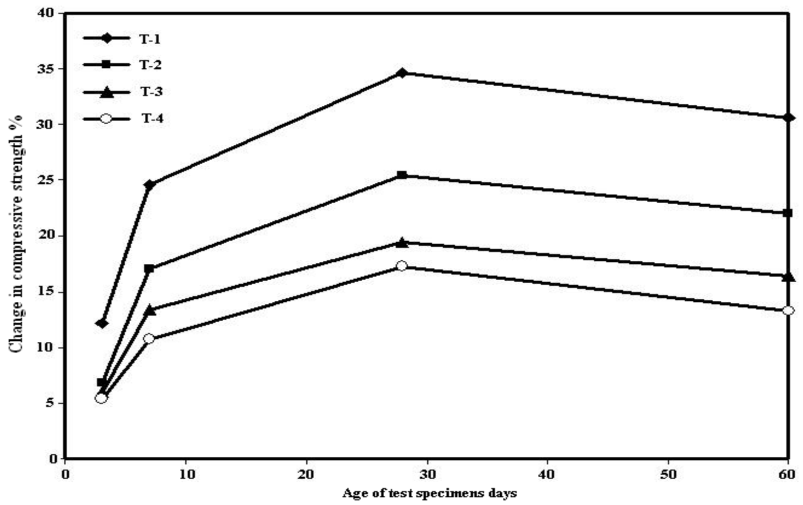

Fig 3 Influence of nano-silica on compressive strength of blended cement

6.4 Comparison of XRD patterns between OPC, Reference and Test samples:

Fig. 4 shows that powder X – ray diffraction patterns of OPC, reference and test samples. OPC, reference and test sample were cured for 28 days before being subjected to XRD technique. After employing XRD for above three samples, calcium hydroxide (CH) was found out, at 17.9^0, 47.1^0 and C_3S was found out at 28.8^0, 32.4^0, 33.7^0. These observation demonstrated that rate of reaction of silica from nano-silica was faster than the silica fume with CH, hence, extra quantity of C-S-H was produced, their by extra strength was contributed to test specimens. Apart that, nano-silica acted as filler material in pore of cement paste matrix, so that voids were minimised, this also contributed extra strength.

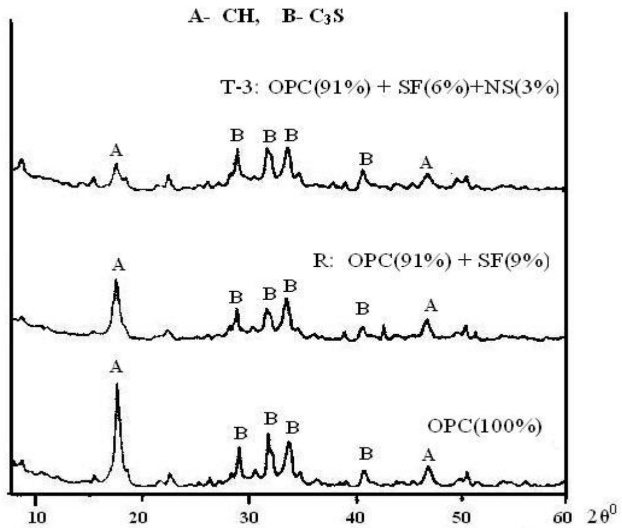

Fig 4 Comparison of XRD patterns between OPC, reference and test samples at age of 28 days

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