

Experiment of Fly-Ash Mix SiO₂ for Variation of Strength in Geopolymer Concrete - A Work Paper

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Abstract— Fresh fly ash-based Nano-Silica concrete has been able to remain workable up to at least 120 minutes without any sign of setting and without any degradation in the compressive strength. Providing a rest period for fresh concrete after casting before the start of curing up to five days increased the compressive strength of hardened concrete. The elastic properties of hardened fly ash-based Nano-Silica concrete, i.e. the modulus of elasticity, the Poisson's ratio, and the indirect tensile strength, are similar to those of ordinary Portland cement concrete.

Keywords: Concrete, Fly-Ash Mix Nano-Silica, Compressive Strength, Tensile Strength, Portland cement, Variability

I. INTRODUCTION

The various materials used in the production of concrete, cement plays a major role due its size and adhesive property. So, to produce concrete with improved properties, the mechanism of cement hydration has to be studied properly and better substitutes to it have to be suggested. Different materials known as supplementary cementitious materials or SCMs are added to concrete improve its properties. Some of these are fly ash, blast furnace slag, rice husk, Nano-Silica fumes and even bacteria. Of the various technologies in use, Fly-Ash-technology looks to be a promising approach in improving the properties of concrete.

The stress-strain relations of fly-ash based Nano-Silica concrete fit well with the expression developed for ordinary Portland cement concrete. This work primarily deals with the compressive strength characteristics such as water absorption super plasticizer used in high performance concrete a set of 4 different concrete mixture were cast and tested with different cement replacement levels of Fly ash (FA) with Nano-Silica (NS) as addition by wt of Cement and/or each trial super plasticizer has been added at constant values to achieve a constant range of slump for desired work ability with a constant water-binder (w/b) ratio of 0.30.

II. LITERATURE REVIEW

A comparative analysis of this work has been presented in the summary of this chapter which will highlight the significance of each work. Out of the numerous work done in the field only a few relevant works have been highlighted in the next section.

1) [Sekari and Razzaghi (2017)] studies the effect of constant content of Fly-Ash ZrO₂, Fe₂O₃, TiO₂, and Al₂O₃ on the properties of concrete. The results showed that all the Fly-Ash particles have noticeable influence on improvement on durability properties of concrete but the contribution of Fly-Ash Al₂O₃ on improvement of mechanical properties of HPC is more than the other Fly-Ash particles.

2) [Girao et al., Yazdanbakhsh et al., (2019)] The incorporation of nano-additives and nano-cement replacements such as silica fume, nano-SiO₂, nano-clay, carbon nanotubes and nano-fly ash in cement matrix has significantly refined the pastes microstructure. Furthermore, it has directly improved strength to the cement pastes and enhanced the durability of mortar and concrete. Because of the cement's complex, hierarchical morphology, even small changes at material chemistry level strongly influence the microstructural morphology and the associated macro scale behavior.

3) [Huaqing Liu, Yan Zhang, Ruiming Tong, Zhaoqing Zhu, and Yang Lv (2020)] Surface protection has been accepted as an effective way to improve the durability of concrete. In this study, nanosilica (NS) was used to improve the impermeability of cement-fly ash system and this kind of material was expected to be applied as surface protection material (SPM) for concrete. Binders composed of 70% cement and 30% fly ash (FA) were designed and nanosilica (NS, 0–4% of the binder) was added. Pore structure of the paste samples was evaluated by MIP and the fractal dimension of the pore structure was also discussed. The workability of fresh concrete and the compressive strength of hardened concrete increase.

III. METHODOLOGY

The details of the properties of the materials used, the method followed to design the experiment and the test procedures followed. The theory is supplemented with a number of pictures to have a clear idea on the methods.

1) Physical Properties of Nano-Silica:

Physical properties	Nano-Silica
Particle shape	Multifaceted
Appearance	Black & glassy
Type Air	Cooled
Specific gravity	3.51
Bulk density at 250 C (Ton/m ³)	1.8 - 2.2
Hardness	5 – 7 Mohs
pH	6.5
Conductivity at 250	Nil
Moisture Content	< 0.1%

2) Chemical Properties of Nano-Silica:

Chemical component	% of Chemical component
SiO ₂	33-35 %
Fe ₂ O ₃	40-44%
Al ₂ O ₃	4-6%
CaO	0.8-1.5%
MgO	1-2%

3) Properties of Fly-Ash

TEST ITEM	STANDARD REQUIREMENTS	TEST RESULTS
SPECIFIC SURFACE AREA (m ² /g)	200 + 20	202
PH VALUE	3.7 – 4.5	4. 12
LOSS ON DRYING @ 105 DEG.C (5)	< 1. 5	0. 47
LOSS ON IGNITION @ 1000 DEG.C (%)	< 2.0	0.66
SIEVE RESIDUE (5)	< 0. 04	0. 02
TAMPED DENSITY (g/L)	40 – 60	44
SiO ₂ CONTENT (%)	> 99. 8	99. 88
CARBON CONTENT (%)	< 0. 15	0. 06
CHLORIDE CONTENT (%)	< 0. 0202	0. 009
Al ₂ O ₃	< 0. 03	0. 005
TiO ₂	< 0. 02	0. 004
Fe ₂ O ₃	< 0. 003	0. 001

B. Proportion of Volume of Coarse Aggregate and Fine Aggregate Content:

- Volume of coarse aggregate per unit volume of total aggregate (ISC: 10262-1982) = 0.64
- (This is corresponding to 20 mm size aggregate and Zone III fine aggregate for water-cement ratio of 0.50)
- As the water-cement ratio is lowered by 0.05, the proportion of volume of coarse aggregate is increased by 0.01 (ref. Table 6 of IS: 10262-1982)
- Corrected volume of coarse aggregate per unit volume of total aggregate = (0.64+0.014) = 0.654
- Volume of fine aggregate per unit volume of total aggregate = 1-0.654 =0.346





Fig: concrete cubes casted in the mould



Fig: shows some concrete specimen cast in laboratory

C. Compressive Strength Test

The compressive strength of specimens is determined after 7 and 28 days of curing with surface dried condition as per Indian Standard IS: 516-1959. Three specimens are tested for typical category and the mean compressive strength of three specimens is considered as the compressive strength of the specified category.

IV. EXPERIMENTAL RESULTS

7-DAY TEST RESULT

Sample No.	Weight (kg)	Load (ton)	Compressive Strength (MPa)
Specimen 1	6.68	43	18.75
Specimen 2	7.24	54	23.54
Specimen 3	7.35	50	21.8
Average Strength (MPa)			21.36

Table 1: Compressive Strength of M20 Grade with 15% Fly Ash & 0% Nano Silica

Sample	0.5% b.w.c			1% b.w.c			2% b.w.c			2.5% b.w.c		
	weight in kg	load in ton	Comp. strength	weight in kg	load in ton	Comp. strength	weight in kg	load in ton	Comp. strength	weight in kg	load in ton	Comp. strength
S-1	6.98	49	21.36	6.92	50	21.80	7.06	54	23.544	7.12	52	22.672
S-2	7.11	52	22.67	7.28	53	23.11	7.64	57	24.852	7.72	55	23.98
S-3	7.02	54	23.54	7.95	55	23.98	7.98	62	27.032	8.08	60	26.16
Average Strength			22.52	Av. Strength		22.96	Av. Strength		25.14	Av. Strength		24.27

Table 2: 7 days Compressive Strength in (MPa) of M20 Grade with different % of Nano-Silica & 15% Fly Ash

14-DAY TEST RESULT

Sample No.	Weight (kg)	Load (tonne)	Compressive Strength (MPa)
Specimen 1	6.92	44	19.18
Specimen 2	7.18	55	23.98
Specimen 3	7.22	52	22.672
Average Strength (MPa)			21.94

Table 3: Compressive Strength in (MPa) of M20 Grade plain specimen for 14 day & 0% Nano Silica

Sample	0.5% b.w.c			1% b.w.c			2% b.w.c			2.5% b.w.c		
	weight in kg	load in ton	Comp. strength	weight in kg	load in ton	Comp. strength	weight in kg	load in ton	Comp. strength	weight in kg	load in ton	Comp. strength
S-1	7.24	51.4	22.416	7.18	53	23.12	7.24	56.96	24.836	7.08	56.4	24.60
S-2	7.02	54.9	23.944	6.97	58	25.292	7.08	61.61	26.864	6.72	60.8	26.5
S-3	6.91	58	25.294	7.36	61.3	26.74	7.41	64.33	28.052	7.11	62.4	27.2
Average Strength			23.88	Av. Strength		25.08	Av. Strength		26.58	Av. Strength		26.10

Table 4: 14 days Compressive Strength in (MPa) of M20 Grade with different % of Nano-Silica & 15% Fly Ash

28-DAY TEST RESULT			
Sample No.	Weight (kg)	Load (tonne)	Compressive Strength (MPa)
Specimen 1	7.38	76	23.686
Specimen 2	7.21	74	22.46
Specimen 3	6.96	68	26.648
Average Strength (MPa)			24.26

Table 5: Compressive Strength of M20 Grade plain specimen for 28 days

Sample	0.5% b.w.c			1% b.w.c			2% b.w.c			2.5% b.w.c		
	weight in kg	load in ton	Comp. strength	weight in kg	load in ton	Comp. strength	weight in kg	load in ton	Comp. strength	weight in kg	load in ton	Comp. strength
S-1	6.86	53	23.136	7.36	55.56	24.226	7.48	57.48	25.064	7.42	56.77	24.752
S-2	7.14	60	26.22	7.52	62.16	27.10	7.56	64.62	28.176	7.54	63.77	27.804
S-3	7.04	63.76	27.80	7.24	64.49	28.116	7.30	67.39	29.384	7.28	65.79	28.686
Average Strength			25.72	Av. Strength			26.48	Av. Strength			27.54	27.08

Table 6: 28 days Compressive Strength in (MPa) of M20 Grade with different % of Nano Nano-Silica & 15% Fly Ash

7-DAY TEST RESULT			
Sample No.	Weight (kg)	Load (tonne)	Compressive Strength (MPa)
Specimen 1	8.65	62	27.032
Specimen 2	8.81	84	36.624
Specimen 3	8.92	75	32.7
Average Strength (MPa)			32.11

Table 7: Compressive Strength of M30 Grade plain specimen for 7 day & 0% Nano Silica

Sample	0.5% b.w.c			1% b.w.c			2% b.w.c			2.5% b.w.c		
	weight in kg	load in ton	Comp. strength	weight in kg	load in ton	Comp. strength	weight in kg	load in ton	Comp. strength	weight in kg	load in ton	Comp. strength
S-1	9.04	76	33.136	9.10	78	34.008	9.18	84	37.368	9.08	82	35.752
S-2	9.12	80	34.88	9.14	84	36.624	9.45	89	38.304	9.38	86	37.496
S-3	9.0	84	36.624	9.14	87	37.932	9.26	95	39.02	9.20	91	39.676
Average Strength			34.88	Av. Strength			36.18	Av. Strength			38.23	37.641

Table 8: 7 days Compressive Strength in (MPa) of M30 Grade with different % of Nano-Silica & 15% Fly Ash

14-DAY TEST RESULT			
Sample No.	Weight (kg)	Load (tonne)	Compressive Strength (MPa)
Specimen 1	8.78	68	29.648
Specimen 2	8.86	86	37.496
Specimen 3	9.06	78	34.008
Average Strength (MPa)			33.717

Table 8: Compressive Strength of M30 Grade plain specimen for 14 day & 0% Nano Silica

Sample	0.5% b.w.c			1% b.w.c			2% b.w.c			2.5% b.w.c		
	weight in kg	load in ton	Comp. strength	weight in kg	load in ton	Comp. strength	weight in kg	load in ton	Comp. strength	weight in kg	load in ton	Comp. strength
S-1	9.36	82	35.752	9.78	92	37.112	9.84	95	38.12	9.81	93	37.148
S-2	9.13	87	37.932	9.41	95	38.32	9.67	97	40.692	9.56	96	40.016
S-3	8.98	92	40.112	9.84	96	41.216	9.96	99	42.064	9.88	97	41.52
Average Strength			37.93	Av. Strength			38.88	Av. Strength			40.292	39.56

Table 9: 14 days Compressive Strength in (MPa) of M30 Grade with different % of Nano-Silica & 15% Fly Ash

28-DAY TEST RESULT			
Sample No.	Weight (kg)	Load (tonne)	Compressive Strength (MPa)
Specimen 1	8.82	72	31.392
Specimen 2	8.89	89	38.804
Specimen 3	9.06	82	35.752
Average Strength (MPa)			35.31

Table 10: Compressive Strength of M30 Grade plain specimen for 28 days & 0% Nano Silica

Sample	0.5% b.w.c			1% b.w.c			2% b.w.c			2.5% b.w.c		
	weight in	load in	Comp. strength	weight in	load in	Comp. strength	weight in	load in	Comp. strength	weight in	load in	Comp. strength

	kg	ton		kg	ton		kg	ton		kg	ton	
S-1	9.39	85	37.06	9.91	94	40.984	9.96	97	42.292	9.91	95	41.42
S-2	9.21	89	38.804	9.64	96	41.856	9.97	98	42.728	9.64	97	42.292
S-3	9.08	94	40.984	9.96	98	42.728	9.98	99	43.164	9.96	99	43.164
Average Strength			38.94	Av. Strength		41.85	Av. Strength		42.728	Av. Strength		42.292

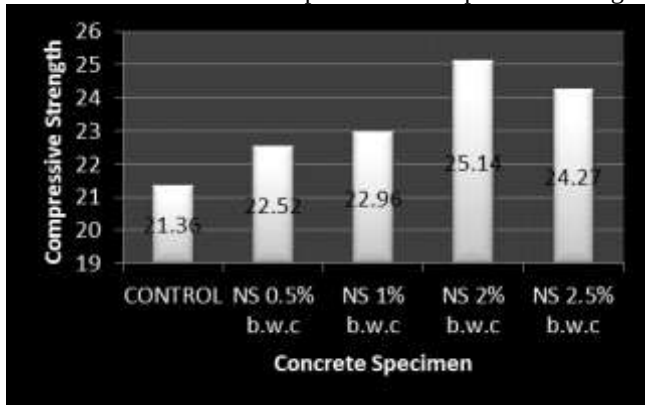
Table 11: 28 days Compressive Strength in (MPa) of M30 Grade with different % of Nano-Silica & 15% Fly Ash

A. Comparison of Compressive Strength Results:

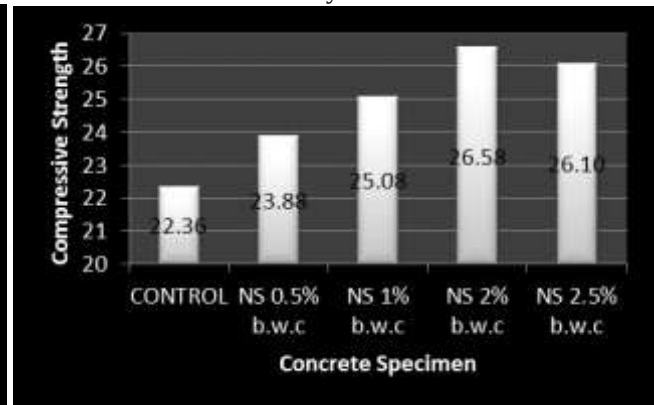
The change in compressive strength for the blended sample (in %) for 7, 14 and 28 day is shown in Table respectively. A graphical representation of this result is shown in Fig. The change in compressive strength from 7 days 14 days to 28 day is shown.

different % of Nano Nano-Silica & 15% Fly Ash	7days		14 days		28 days	
	strength (mpa)	increase in strength (%)	strength (mpa)	increase in strength (%)	strength (mpa)	increase in strength (%)
CONTROL	21.36	-	21.94	-	24.26	-
NS 0.5% b.w.c	22.52	3.19	23.88	6.80	25.72	6.01
NS 1% b.w.c	22.96	10.98	25.08	12.16	26.48	9.15
NS 2% b.w.c	25.14	19.0	26.58	18.87	27.54	13.52
NS 2.5% b.w.c	24.27	17.82	26.10	16.73	27.08	11.62

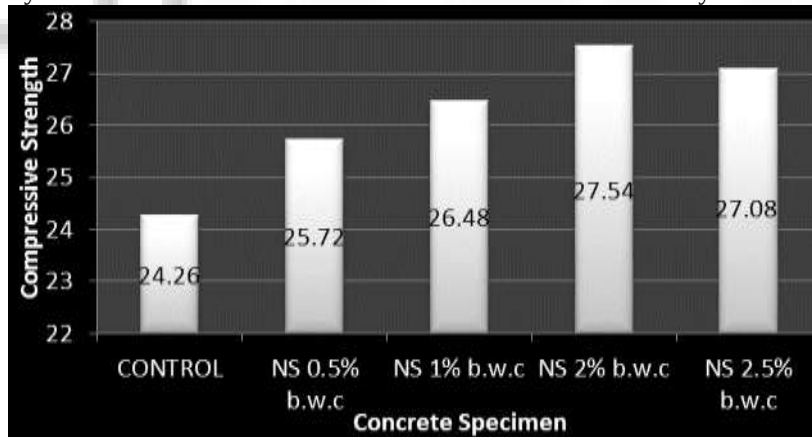
Table 4.13: Comparison of compressive strength for M20 Grade and 15% of Fly-ASH of Concrete



(a) compressive strength in 7days with M20 Grade and 15% of Fly-ASH of Concrete



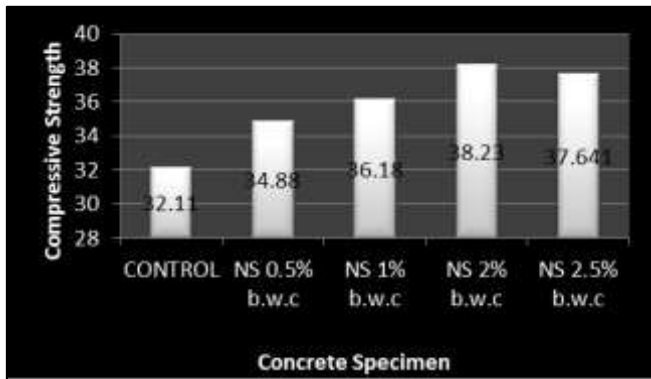
(b) compressive strength in 14 days with M20 Grade and 15% of Fly-ASH of Concrete



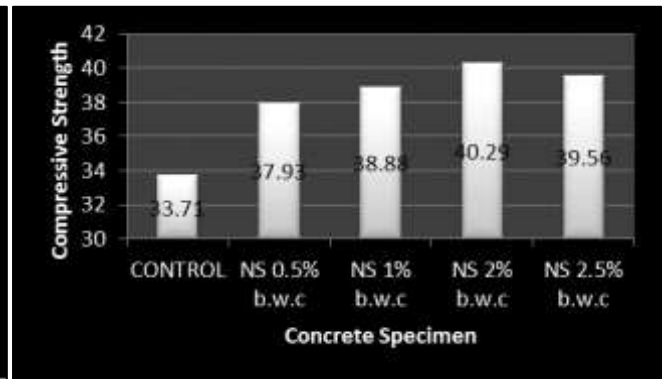
(c) compressive strength in 28 days with M20 Grade and 15% of Fly-ASH of Concrete

different % of Nano Nano-Silica & 15% Fly Ash	7days		14 days		28 days	
	strength (mpa)	increase in strength (%)	strength (mpa)	increase in strength (%)	strength (mpa)	increase in strength (%)
CONTROL	32.11	-	33.71	-	35.31	-
NS 0.5% b.w.c	34.88	8.62	37.93	12.49	38.94	10.26
NS 1% b.w.c	36.18	12.70	38.88	15.33	41.85	18.51
NS 2% b.w.c	38.23	19.06	40.29	19.51	42.728	20.98
NS 2.5% b.w.c	37.641	17.22	39.56	17.35	42.292	19.75

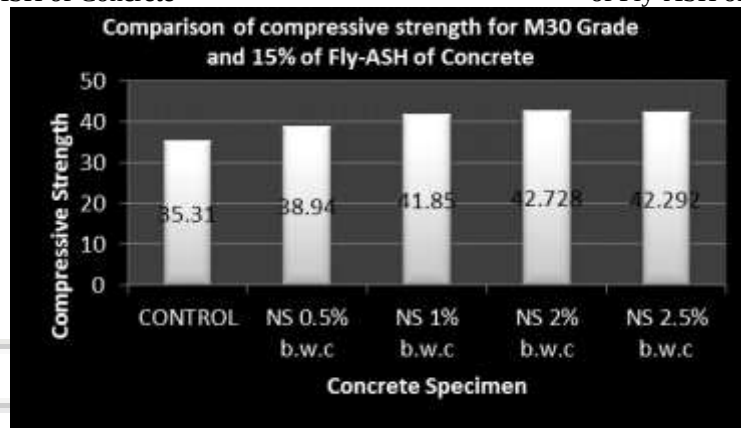
Table 4.14: Comparison of compressive strength for M30 Grade and 15% of Fly-ASH of Concrete



(a) compressive strength in 7days with M30 Grade and 15% of Fly-ASH of Concrete



(b) compressive strength in 7days with M30 Grade and 15% of Fly-ASH of Concrete



(c) compressive strength in 7days with M30 Grade and 15% of Fly-ASH of Concrete

The tables and graphs show that there is an improvement in the early strength of concrete blended with Fly-Ash Mix Nano-Silica but later the increase in strength is subdued.

V. CONCLUSION

From the test results, the conclusions are justified in this section. The conclusions drawn are:

- 1) From the compressive strength results, it can be observed that increase in compressive strength of concrete is observed on addition of a certain minimum quantity of Fly-Ash Mix nano SiO₂. The increase in strength is maximum for NS 2% b.w.c and least for NS 0.5% b.w.c.
- 2) On addition of Fly-Ash Mix SiO₂ there is a substantial increase in the early-age strength of concrete compared to the 28 day increase in strength.

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