A Work Paper on Experimental Analysis of Fly-Ash mix Nano-Silica in Geopolymer Concrete for Economical Behavior of the Structure

Amir Usmani[1] Prof. Kamni Laheriya[2]
[2]Assistant Professor
[1,2]Department of Civil Engineering
[1,2]SSSUTMS Sehore (M. P.), India

Abstract— Fresh fly ash-based Nano-Silica in Geopolymer 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 in Geopolymer concrete after casting before the start of curing up to five days increased the compressive strength of hardened in Geopolymer concrete. The elastic properties of hardened fly ash-based Nano-Silica in Geopolymer concrete, i,e. the modulus of elasticity, the Poisson's ratio, and the indirect tensile strength, are similar to those of ordinary Portland cement in Geopolymer concrete.
Keywords: Geopolymer concrete, Fly-Ash mix Nano-Silica, compressive strength, tensile strength, Portland Cement, Variability

I. INTRODUCTION

The various materials used in the production of Geopolymer concrete, cement plays a major role due its size and adhesive property. So, the produce to make Geopolymer 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 Geopolymer 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 Geopolymer concrete.

The stress-strain relations of fly-ash based Nano-Silica in Geopolymer concrete fit well with the expression developed for ordinary Portland cement in Geopolymer concrete. The types and relative amounts of incombustible matter in the coal determine the chemical composition of fly ash. This work primarily deals with the compressive strength characteristics such as water absorption super plasticizer used in high performance in Geopolymer concrete a set of 4 different in Geopolymer concrete mixture were cast and tested with different cement replacement levels of Fly ash (FA) with nano 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.

[Ali Nazari et.al. (2016)] studied strength and percentage water absorption of SCC containing different amount of GGBFS and TiO2 Fly-Ash particles. The findings of the experimentation are that replacement of Portland cement with up to 45% weight of GGBNS and up to 4% weight of TiO2 Fly-Ash particles gives a considerable increase to the compressive, split tensile and flexural strength of the blended in Geopolymer concrete.

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

[Girao et al., Yazdanbakhsh et al., (2019)] The incorporation of nano-additives and nano-cement replacements such as silica fume, nano-SiO 2, 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 in Geopolymer concrete.

[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 in Geopolymer 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 in Geopolymer concrete. Binders composed of 70% cement and 30% fly ash (FA) were designed and nanosilica (NS, 0–4% of the binder) was added. The workability of fresh in Geopolymer concrete and the compressive strength of hardened in Geopolymer 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.

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/m3)	1.8 - 2.2
Hardness	5 – 7 Mohs
pH	6.5
Conductivity at 250	Nil
Moisture Content	< 0.1%

Chemical Properties of Nano-Silica:

Chemical component	% of Chemical component
SiO2	33-35 %
Fe2O3	40-44%
Al2O3	4-6%
CaO	0.8-1.5%
MgO	1-2%

Properties of Fly-Ash

TEST ITEM	STANDARD REQUIREMENTS	TEST RESULTS
SPECIFIC SURFACE AREA (m2/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
SiO2 CONTENT (%)	> 99. 8	99. 88
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

A. 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

B. 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	56	24.42
Specimen 3	7.35	52	22.67
Average Strength (MPa)			21.94

Table: 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 kg	load ton	Comp. strength	weight kg	load ton	Comp. strength	weight kg	load ton	Comp. strength	weight kg	load ton	Comp. strength
S-1	6.98	52	22.67	6.92	61	26.596	7.06	66	28.764	7.12	64	27.904
S-2	7.11	63	27.468	7.28	64	27.904	7.64	69	30.084	7.72	68	29.648
S-3	7.02	65	28.34	7.95	66	28.776	7.98	74	32.264	8.08	71	30.956
Average Strength			26.16	Av. Strength		27.76	Av. Strength		30.37	Av. Strength		29.50

Table: 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	46	20.056
Specimen 2	7.18	56	24.416
Specimen 3	7.22	51	22.236
Average Strength (MPa)			22.236

Table: 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 kg	load ton	Comp. strength	weight kg	load ton	Comp. strength	weight kg	load ton	Comp. strength	weight kg	load ton	Comp. strength
S-1	7.24	56	24.416	7.18	70	30.52	7.24	76	33.136	7.08	73	31.828
S-2	7.02	64	27.904	6.97	72	31.392	7.08	79	34.444	6.72	77	33.572
S-3	6.91	69	30.084	7.36	74	32.264	7.41	82	35.752	7.11	80	34.88
Average Strength			27.468	Av. Strength		31.392	Av. Strength		34.444	Av. Strength		33.42

Table: 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	33.136
Specimen 2	7.21	74	32.264
Specimen 3	6.96	68	29.648
Average Strength (MPa)			31.68

Table: 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 kg	load ton	Comp. strength	weight kg	load ton	Comp. strength	weight kg	load ton	Comp. strength	weight kg	load ton	Comp. strength
S-1	6.86	76	33.136	7.36	81	35.316	7.48	84	36.624	7.42	82	35.752
S-2	7.14	71	30.95	7.52	88	38.368	7.56	91	39.676	7.54	89	38.804
S-3	7.04	80	34.88	7.24	86	37.496	7.30	94	40.984	7.28	91	39.676
Average Strength			32.99	Av. Strength		37.06	Av. Strength		39.09	Av. Strength		38.077

Table: 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: 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 kg	load ton	Comp. strength	weight kg	load ton	Comp. strength	weight kg	load ton	Comp. strength	weight kg	load ton	Comp. strength
S-1	9.04	76	33.136	9.10	78	34.008	9.18	84	38.368	9.08	82	35.752
S-2	9.12	80	34.88	9.14	84	36.624	9.45	89	38.804	9.38	86	37.496
S-3	9.0	84	36.624	9.14	87	37.932	9.26	95	41.42	9.20	91	39.676
Average Strength			34.88	Av. Strength		36.188	Av. Strength		39.53	Av. Strength		37.641

Table: 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: 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 kg	load ton	Comp. strength	weight kg	load ton	Comp. strength	weight kg	load ton	Comp. strength	weight kg	load ton	Comp. strength
S-1	9.36	82	35.752	9.78	92	40.112	9.84	95	41.42	9.81	93	40.548
S-2	9.13	87	37.932	9.41	95	41.42	9.67	97	42.292	9.56	96	41.856
S-3	8.98	92	40.112	9.84	96	41.856	9.96	99	43.164	9.88	97	42.292
Average Strength			37.93	Av. Strength		41.13	Av. Strength		42.292	Av. Strength		41.56

Table: 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)			35.316

Table: 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 kg	load ton	Comp. strength	weight kg	load ton	Comp. strength	weight kg	load ton	Comp. strength	weight kg	load ton	Comp. strength
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	38.80	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	41.856	Av. Strength	42.728	Av. Strength	42.292

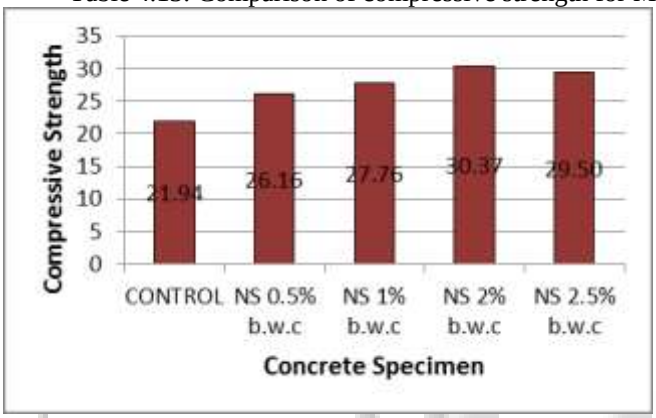
Table 4.12: 28 days Compressive Strength in (MPa) of M30 Grade with different % of Nano-Silica & 15% Fly Ash

A. Comparison of Compressive Strength Results:

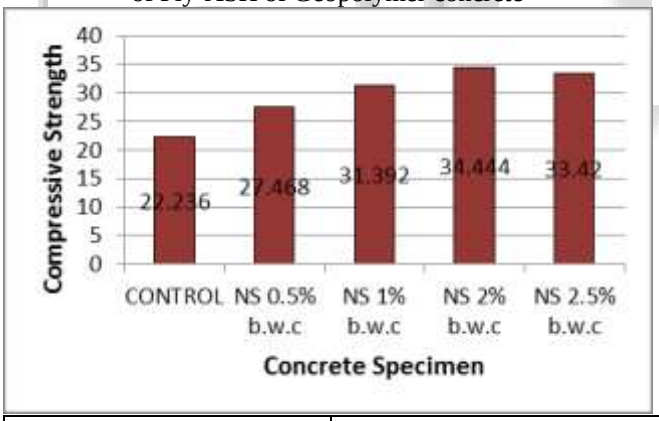
The change in compressive strength for the blended sample (in %) for 7, 14 and 28 day is shown in Table respectively. A graphical representation of this result is shown in Fig. The change in compressive strength from 7 days 14 days to 28 day is shown.

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	21.94	-	22.236	-	31.68	-
NS 0.5% b.w.c	26.16	19.23	27.468	23.52	32.99	4.13
NS 1% b.w.c	27.76	26.52	31.392	41.17	37.06	16.98
NS 2% b.w.c	30.37	38.42	34.444	54.90	39.09	23.39
NS 2.5% b.w.c	29.50	34.45	33.42	50.30	38.077	20.19

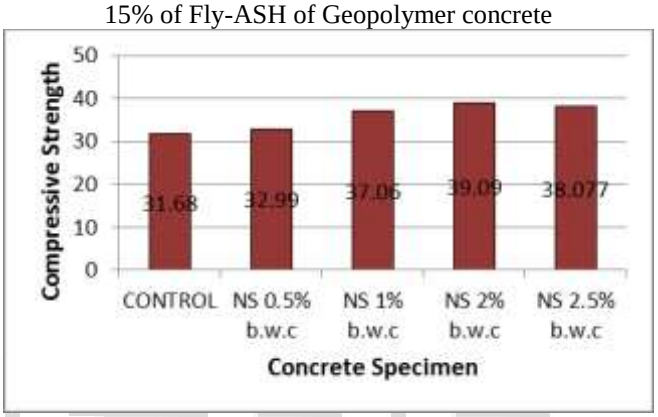
Table 4.13: Comparison of compressive strength for M20 Grade and 15% of Fly-ASH of In Geopolymer concrete



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



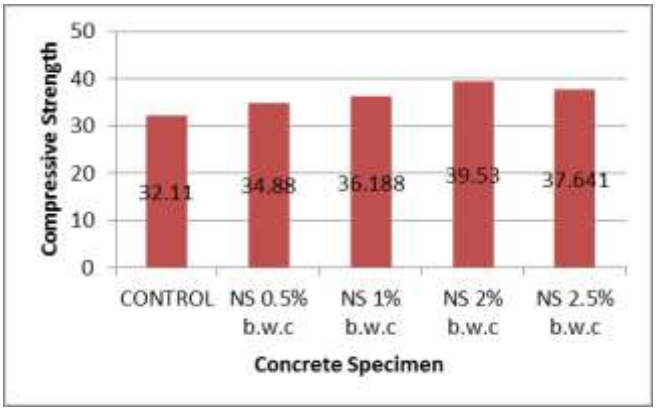
(b) compressive strength in 14 days with M20 Grade and 15% of Fly-ASH of Geopolymer concrete



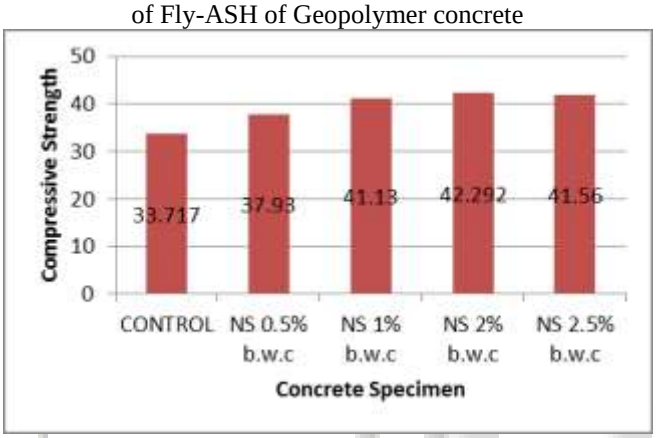
(c) compressive strength in 28 days with M20 Grade and 15% of Fly-ASH of Geopolymer Concret

different % of Nano-Silica & 15% Fly Ash	7days		14 days		28 days	
	strength (mpa)	increase strength (%)	strength (mpa)	increase strength (%)	strength (mpa)	increase strength (%)
CONTROL	32.11	-	33.717	-	35.316	-
NS 0.5% b.w.c	34.88	8.62	37.93	12.49	38.94	10.26
NS 1% b.w.c	36.188	12.70	41.13	21.98	41.856	18.51
NS 2% b.w.c	39.53	23.11	42.292	25.43	42.728	20.98
NS 2.5% b.w.c	37.641	17.22	41.56	23.26	42.292	19.75

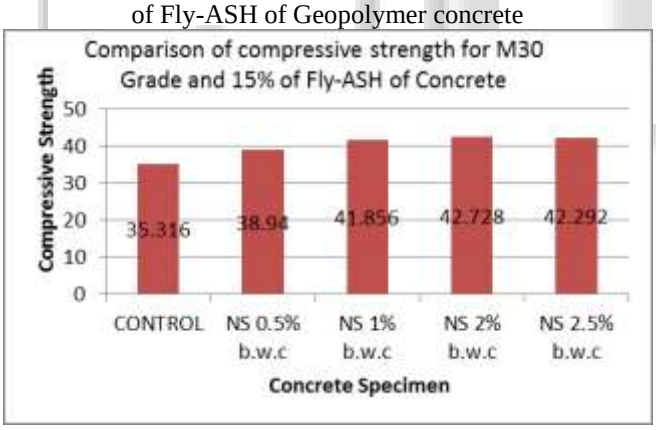
Table: Comparison of compressive strength for M30 Grade and 15% of Fly-ASH of Geopolymer concrete



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



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



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

The tables and graphs show that there is an improvement in the early strength of Geopolymer 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:

- From the compressive strength results, it can be observed that increase in compressive strength of Geopolymer 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.
- On addition of Fly-Ash Mix SiO2 there is a substantial increase in the early-age strength of Geopolymer concrete compared to the 28 day increase in strength.

REFERENCES

[1] Ali Nazari, Shadi Riahi, Shirin Riahi, Saydeh Fatemeh Shamekhi and A. Khademno. (2010). Mechanical properties of cement mortar with Al2O3 Fly-Ash Mixparticles. *Journal of American Science 6(4)*, 94-97.

[2] 2. Alireza Naji Givi, Suraya Abdul Rashid, Farah Nora A. Aziz and Mohamad Amra Mohd Salleh (2010). Experimental investigation of the size effects of SiO2 Fly-Ash Mix particles on the mechanical properties of binary blended in Geopolymer concrete. *Composites: Part B 41*, 673-677.

[3] 3. G.Quercia and H.J.H.Brouwers (2010). Application of Fly-Ash MixNano-Silica (nS) in in Geopolymer concrete mixtures. *8th fib PhD symposium in Kgs. Lyngby, Denmark.*

[4] 4. M.S. Morsy, S.H. Alsayed and M. Aqel. (2010). Effect of Fly-Ash Mix clay on mechanical properties and microstructure of Ordinary Portland Cement mortar. *International Journal on Civil Engineering & Environmental Engineeering IJCEE-IJENS Vol. 10 No. 01*.

[5] 5. Shekari, A. H. and Razzaghi, M. (2011). Influence of Fly-Ash Mixparticles on durability and mechanical properties of SCC with GGBFS as binder. *Energy and buildings Vol. 43*, 995-1002.

[6] 6. Givi, A. N. and Rashid, S. A. (2011). The effect of lime solution on the properties of SiO2 Fly-Ash Mixparticles binary blended in Geopolymer concrete. *Composites (Part B) Vol. 42*, 562-569.

[7] 7. Chahal, Navneet and Rafat Siddique (2012). Influence of bacteria on the compressive strength, water absorption and rapid chloride permeabilty of in Geopolymer concrete incorporating siloca fume. *Construction and Building Materials 37*, 645-651.

[8] 8. A.M. Said, M.S. Zeidan, M.T. Bassuomi and Y. Tian. (2012). Properties of in Geopolymer concrete incorporating Fly-Ash Mix-Nano-Silica. *Construction and Building Materials 36*, 838-844.

[9] 9. Heidari, A., and Tavakoli, D. (Sept 2012). A study of mechanical properties on ground ceramic powder in Geopolymer concrete incorporating Fly-Ash Mix SiO2 particles. *Construction and Building Materials Vol. 38*, 255-264.

[10] 10. Navneet Chahal and Rafat Siddique (2013). Permeation properties of in Geopolymer concrete made with fly ash and Nano-Silica fume: Influence of ureolytic bacteria. *Construction and Building Materials 49*, 161-174.

