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Utilization of Nano Silica & Fly Ash on the Workability and Compressive Strength of Ordinary Portland Cement

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Abstract: This paper focusses on studying the utilization of nano silica and flyash on the compressive strength of concrete containing different percentage of nano silica (NS) ranging from 0.3 to 1% (by weight) and a fixed proportion of fly ash (20% by weight) as a partial replacement of cement. The compressive strength of concrete is measured at 7 days & 28 days respectively. The effects of NS in microstructure development and pozzolanic reaction of pastes containing above fly ash content are also studied through Field Emission Scanning Electron Microscope (FESEM).Result shows that the maximum compressive strength is obtained with 20% of fly-ash and 0.75% of nano silica by weight of cement for both M20 & M30 grades of ordinary concrete. The strength found to be 20.76 MPa and 27.11 MPa for 7 days and 28 days respectively for M20 grade of nano silica & fly ash mixed concrete while the compressive strength of ordinary concrete of M20 grade comes out to be 15.06 MPa and 24.88 MPa for 7 days and 28 days respectively. Hence the maximum percentage increase in the compressive strength comes out to be 8.96 % for M20 grade of concrete in 28 days also the compressive strength found to be 31.73 MPa and 40.10 MPa for 7 days and 28 days respectively for M30 grade of nano silica & fly ash mixed concrete while the compressive strength of ordinary concrete comes out to be 23.17 MPa and 34.91 MPa for 7 day and 28 days respectively. Hence the maximum percentage increase in the compressive strength comes out to be 14.86 for M30 grade of concrete at 28 days.The test conducted on it shows a considerable increase in early-age compressive strength and a small increase in the overall compressive strength of the ordinary concrete.The FESEM analysis also supports the above findings.
Key words: Compressive strength, Concrete, FESEM, Flyash, Nanosilica

I. INTRODUCTION

Concrete is the basic material for the construction work of present as well as future generations. The wide use of it in structures, highways, buildings to factories, from bridges to airports, makes it one of the most useful materials of the 21st century. At present various infrastructure development projects are being undertaken throughout the country and it is contributing rapid economic growth of the nation. In most of the infrastructural project, cement concrete is used as basic material. Out of the various materials used in the production of concrete, cement plays an important role due to its adhesive property. In order to enhance the properties such as strength, durability etc. of cement concrete mix various research work has already been carried out. Most of the researchers have used materials such as fly-ash, blast furnace slag, rice husk, silica fume etc. for this purpose.

Reducing the necessary amount of Portland cement without reducing the performance of concrete is significant for big projects that require a large amount of cement. Furthermore, Portland cement clinker production consumes large amounts of energy and has a notable environmental impact, which involves massive quarrying for raw materials because it 1.7 tons are required to produce 1 ton of clinker and the emission of greenhouse and other gases into the atmosphere.

Min-Hong Zhang et al., (2012) investigated about the impact of nano silica and high volume slag mortar on setting time and early strength and it is seen that hydration rate increments with expansion of nano-silica, compressive strength of slag mortar ascends with increment in nano-silica doses from 0.5 to 2% by weight of cement. It is discovered that 2% nano-silica lessens initial and final setting time and compressive strength increments by 22% and 18% at 3 days and 7 days respectively with addition of 50% slag.

AM Said et al., (2012) examined the impact of colloidal nano-silica (CNS) on concrete by blending it with class F fly-ash and noticed that the performance of concrete with or without fly ash was considerably improved by the addition of variable amount of colloidal nano-silica. The blend containing 30% FA and 6% CNS gives maximum strength. The porosity and threshold pore diameter were also found extremely low.

Shaikh et al., (2014) have investigated the compressive strength of mortars and concrete containing different high volume fly-ash contents such as 40% to 70% by weight as partial replacement of cement and observed that 2% nano-silica gives maximum 7 and 28 days compressive strength. On adding of 2% nano-silica in the HVFA mortars, improvement in 3 days strength was noticed and 7 days compressive strength containing 40% and 50% fly-ash increases by 5% and 7% respectively. However, this improvement is not observed beyond 50% fly-ash content.

Alvin Harison et al., (2014) studied the effect of fly-ash on compressive strength of concrete and replaced Portland pozzolona cement (PPC) by fly-ash with 0%, 10%, 20%, 30%, 40%, 50% & 60% by weight of cement for M25 mix with w/c ratio of 0.46.The author observed that strength increased up to 30% fly-ash content and after that it decreased. However, increase in strength was prominent at 20% replacement level. The early 7 days strength of concrete mix found to be 31.16 MPa which is 74% of 28 days strength (36.6 MPa).

Garcia et al.,(2015) have investigated that nano-silica accelerates hardening, increases density, decreases porosity, improves binding of cement paste and aggregates. It is found that more than 6% nano-silica is not recommended due to chemical incompatibility.

Rishabh Joshi (2017) studied the impact on compressive strength of concrete by partial replacement of cement with 0%, 10%, 20% also, 30% of fly ash for M20 grade of concrete.

Test outcomes demonstrate that workability and durability of concrete increases with increment in fly ash content certain percentages. However, with further increment of fly-ash content, compressive strength of cement concrete mix gets reduced. The optimum replacement of cement with fly ash is 30%.

Behzadian and Shahrajabian (2019) examined the mechanical properties of concrete having waste polyethylene terephthalate (PET) and nano-silica. They added different percentages of nano-silica to the concrete containing 10% of waste PET aggregates. Flexural, tensile and compressive strength of the concrete increased by 27%, 30% and 9% respectively compared to the virgin concrete.SEM analysis showed that interfacial transition zone between cement paste and the PET aggregates is considerably improved on addition of nano-silica.

Yanqun Sun et al., (2020) have explored the consolidated effect of nano-CaCO3 and fly-ash on the mechanical properties and durability of concrete. In the first phase of their experiment, nine types of concrete mixtures were prepared using w/c ratio as (0.4, 0.5 & 0.6), fly-ash as (15%, 20%, and 25% by weight of cement), and nano$CaCO_3$ as (1%, 2% & 3%) by weight of cement. They carried out orthogonal analysis on these mixes and found mixture prepared with w/c ratio of 0.4, fly-ash 20% and Nano-CaCO3 1% as optimal concrete.

Their experiments also revealed that in the initial stage of concrete mix Nano-CaCO3 contributed for its compressive strength .However in the later stage its effect was very limited. Scanning electron microscopy (SEM) analysis revealed that the filling, seeding and pozzolanic effects are responsible for the concrete performance.

Pathak and Vesmawala (2023) in their experimental work describes the fracture parameters of concrete using TiO_2 Nano powder (NT) (1, 2, and 3%) and ground granulated blast furnace slag (GGBS) (30%).The size effect method (SEM) and work of fracture (WFM) were used for all mixes to analyze the fracture properties of concrete. The basic mechanical properties of concrete viz. compressive strength, flexural strength, and tensile strength were studied.

The results showed that, the decrease in the w/c ratio from 0.4 to 0.35 in concrete: (a) fracture energy increases, (b) fracture toughness increases, (c) characteristic length decreases, (d) brittleness number decreases, while the increase in the percentage of NT from 1 to 3% in concrete: (a) fracture energy increases, (b) fracture toughness increases, (c) characteristic length decreases, (d) brittleness number increases.

The present paper aimed at the study on the effect of fly ash and nano silica on the compressive strength of cement concrete mix using partial replacement of cement with fixed percentage of fly-ash (20% by weight) and varied percentage of nano silica (0.3 to 1% by weight) after 7 & 28 days.

The effects on pore structure of concrete were further examined using Field Emission Scanning Electron Microscope (FESEM) for support of the findings from lab tests.

II. MATERIALS USED

A. Cement

Ordinary Portland cement of 53 grade conforming to IS: 12269-1987 is used for preparing cement concrete specimens. Various physical properties tests were conducted on the cement and the test result is given in Table 1as below.

Table 1: Some Physical properties of cement (OPC 53)

S. No.	Properties	Test results	IS Requirements
1	Initial setting time	1hr 22 min	Min 30 minutes
2	Final setting time	5hr 40 min	Max 600 minutes
3	Standard consistency	33.5 mm	33-35 mm
4	Fineness	7 %	10%
5	Specific gravity	2.9	3.15

B. Aggregate

The sand and the coarse aggregate used in the concrete were crushed limestone aggregates. The water absorption, particle size distribution or sieve analysis and specific gravity tests of aggregates (fine & course)were performed as explained below.

1) Tests on Fine Aggregate

a) Sieve Analysis

The test was conducted by taking 1000 gm of sand sample and the result is given in **Table 2**.

Fig. 1 Sieve Test of Fine Aggregates

Table 2: Sieve Analysis for Fine aggregate

S. No.	IS-Sieve (mm)	Wt. Retained (gm)	Wt.Retained (%)	Passing (%)	Cumulative % Wt. Retained	Std. % wt. passing for Zone 2 IS: 383-1970
1	4.75	14.5	1.45	98.55	1.45	90-100
2	2.36	37	3.70	94.85	5.15	75-100
3	1.18	246.5	24.65	70.20	29.80	55-90
4	600 µ	205.5	20.55	49.65	50.35	35-90
5	300 µ	287.5	28.75	20.90	79.10	8-30
6	150 µ	177	17.70	3.20	96.80	0-10
7	Pan	32	3.20			

The fineness modulus can be calculated from above table as given below

Fineness modulus = Sum of cumulative % of weight retained / 100

$$FM = \frac{262.5}{100} = 2.63$$

Hence, it can be concluded from the above table and also based on fineness modulus value calculated above that the fine aggregate collected for present work falls under Grading Zone II.

b) Specific Gravity

Specific gravity of fine aggregate can be defined as the ratio of the weight of fine aggregate in air to the weight of equal volume of water displaced by saturated surface dry aggregate(Revised AASHTO T 84). The specific gravity of fine aggregate calculated by pycnometer method(Conforming to Revised AASHTO T 84). The details of test results are as given below:

Specific gravity (G) = D/ C - (A-B)
C = weight of saturated & surface dry aggregate = 500 gm
A = weight of pycnometer bottle + sand + water = 1827 gm
B = weight of pycnometer bottle full with water = 1513 gm
D = weight of oven dry sample = 495 gm
Specific gravity (G) = D/ C – (A–B)
Specific gravity (G) = 495/ 500 – (1827– 1513)
Specific gravity (G) = 2.66

Hence, the specific gravity of fine aggregate comes out to be 2.66.

c) Water Absorption

Water absorption is determined by oven drying method(Conforming to Revised AASHTO T 84). A sample of sand is collected and weight is taken. The sample is spread in the tray and kept in oven at 1000 ˚C temperature for 24 hours.

C = weight of saturated & surface dry aggregate = 500 gm
D = weight of oven dry sample = 495.8 gm
Water absorption = (C – D) / D*100
Water absorption = (500 – 495.8) /500 *100
Water absorption = 0.84 %

Hence, the water absorption of fine aggregate comes out to be 0.84%.

The properties of the fine aggregate obtained from the test results are given in Table 3.

Table 3 Properties of fine aggregate

S. No	Properties	Test Results
1	Specific Gravity	2.66
2	Water absorption	0.84%
3	Fineness Modulus	2.63
4	Grading zone	Zone II

2) Tests on Course Aggregates

a) Sieve Analysis

The sieve analysis of the Coarse aggregate is carried out in the Construction Material Testing lab in NITTTR, Bhopal(Fig. 2). The test was conducted by taking 3000 gm of coarse aggregate sample and the result is given in Table 4

Fig. 2 Sieve Test of Course Aggregates

Table 4 Sieve Analysis of Course Aggregate

S. No	IS-Sieve (mm)	Wt. Retained (gm)	%age Retained	%age Passing	Cumulative % Wt. Retained
1	40	0.00	0.00	100.00	0.00
2	20	72.6	2.42	97.58	2.42
3	10	1681.8	56.06	41.52	58.48
4	4.75	1168.5	38.95	2.57	97.43
5	Pan	77.1	2.57	0	

From the above readings it can be concluded the coarse aggregate used in the study falls under the category of single sized aggregate of nominal size 20 mm as per the IS code 383:2017.

The fineness modulus now can be calculated from the readings in table 4 as follows:
F.M. = Sum of cumulative percentage of wt. retained/100
= (158.33+500)/100
= 6.59

b) Specific Gravity

The specific gravity of coarse aggregate can be defined as the ratio of the weight of coarse aggregate in air to the weight of equal volume of water displaced by saturated surface dry aggregate (Conforming to AASHTO T 85) The specific gravity of coarse aggregate test is performed Construction Material Testing lab in NITTTR, Bhopal.
Weight of the sample taken = 1000 gm
Weight of container + sample + water (A) = 3371 gm
Weight of container + water (B) = 2747 gm
Weight of saturated & surface dry sample (C) = 991 gm
Weight of oven dry sample (D) = 981 gm
Specific gravity (G) = D/ C - (A–B)
Specific gravity (G) = 981 / 991 – (3371 - 2747)
Specific gravity (G) = 2.67
Hence, the specific gravity of coarse aggregate comes out to be 2.67.

c) Water Absorption

C = weight of saturated and dry surface aggregate = 989 gm
D = weight of oven dry sample = 981gm
Water absorption = (C – D) / D*100
Water absorption = (989– 981) / 981*100
Water absorption = 0.816 %
Hence, the water absorption of coarse aggregate comes out to be 0.816 %.

d) Bulk Density

The bulk density of coarse aggregate is calculated according to IS 2386 (Part 3) 1963
Vol. of cylindrical metal container = 15 liters

Weight of container filled with aggregate = 34.7 Kg
Weight of metal container = 9 kg
Weight of aggregate = 34.7 Kg – 9Kg
= 25.7 Kg
Bulk density = Wt. of aggregate ÷ volume of cylindrical metal container
= 25.7 Kg ÷ 15×10-3 m3
= 1.713×103 Kg/m3
= 1713 Kg/m3
So the bulk density of coarse aggregate comes out to be 1713 Kg/m3.
The properties of the coarse aggregate obtained from the test results are given in Table 5.

Table 5 Properties of Coarse Aggregate

S. No.	Properties	Results obtained
1	Specific gravity	2.67
2	Water absorption	0.816 %
3	Fineness modulus	6.59
4	Bulk density	1700

C. Water
Fresh portable water free from any kind of impurities like salt, oil, organic matters etc. is used. Water having pH value varying between 6 to 8 , was used and was free from any kind of alkalinity and salinity was used during mixing and curing of concrete.

D. Nano Silica
Nano Silica is a white fluffy powder which contains highly pure amorphous silica powder. Due to its small particle size it has many properties like large specific surface area, strong surface adsorption, large surface energy, high chemical purity and good dispersion. The size of nanosilica used is 250 nm. The nanosilica used is shown in Fig.3. Chemical properties of nano silica are given in table 6.

Fig.3 Nano Silica Powder

Table 6 Chemical properties of nano silica

S. No.	Chemical component	% of Chemical component
1	SiO2	33-35 %
2	Fe_2O_3	40-44%
3	Al_2O_3	4-6%
4	CaO	0.8-1.5%
5	MgO	1-2%

E. Fly Ash

Pozzolanais siliceous or siliceous and aluminous materials, which in a finely separated structure and within the sight of water, respond with calcium hydroxide at common temperatures to deliver cementitious mixes. The special round shape and molecule size appropriation of fly ash make it decent mineral filler in hot mix asphalt (HMA) applications and improves the fluidity of flowable fill and grout.

Fly ash used in this experiment is shown in Fig.4 and its physical properties are shown in below table 7.

Fig. 4 Fly Ash used in experiment

Table 7 Physical properties of Fly Ash

Physical properties	Fly-ash
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%

III. MIX PROPORTIONS

Test samples were prepared using ordinary cement concrete mix and modified cement concrete mix of M20 & M30 grades of concrete. To arrive at the M20 and M30 grades of concrete mix, a mix design (conforming IS 10262:1982) was carried out, the details of quantity of ingredients are given in table 8 and 9 for M20 & M30 grades of ordinary concrete.

For preparation of test samples cubes of size 150x150x150 mm are casted in cube moulds. After successful casting, the concrete specimens are demoulded after 24 hours and immersed in water for 7 and 28 days maintaining 27 +/- ºC. 12 No. of cubes were prepared using ordinary cement concrete mix, 6 cubes each for M20 and M30 grades. Ordinary cement concrete mix was prepared by basic ingredients like cement, fine aggregate, coarse aggregate and water.

Table 8 Quantity of ingredients for M20 Grade (Ordinary Concrete)

S. No.	INGREDIENTS	QUANTITY
1	CEMENT	11 kg
2	FINE AGGREGATE	15.18 kg
3	COARSE AGGREGATE	28.92 kg
4	WATER	4.8 liters

Table 9 Quantity of ingredients for M30 Grade (Ordinary Concrete)

S. No.	INGREDIENTS	QUANTITY
1	CEMENT	12 kg
2	FINE AGGREGATE	14.67 kg
3	COARSE AGGREGATE	28 kg
4	WATER	4.5 liters

Test samples for modified concrete were prepared with different proportions of nano silica (NS) varying from 0.3 to 1 % and fixed proportion of Fly ash (20% by weight of cement).

The details of the test samples given below:

1) 12 No of cubes were prepared with 20% fly-ash and 0.3% nano-silica replacement with cement, 6 cubes each for M20 and M30 respectively.
2) 12 No of cubes were prepared with 20% fly-ash and 0.5% nano-silica replacement with cement, 6 cubes each for M20 and M30 respectively.
3) 12 No of cubes were prepared with 20% fly-ash and 0.75% nano-silica replacement with cement, 6 cubes each for M20 and M30 respectively.
4) 12 No of cubes were prepared with 20% fly-ash and 1% nano-silica replacement with cement, 6 cubes each for M20 and M30 respectively.

The ingredients used and also the process of preparation of test samples are also shown in figures 5 to 9.

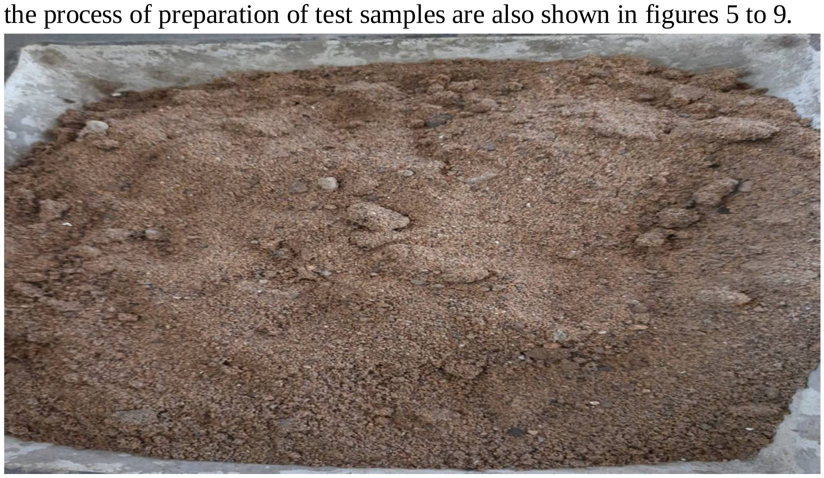

Fig. 5 Fine aggregate used in test sample

Fig. 6 Coarse aggregate used in test sample

Fig. 7 Mixing & Tamping concrete in layers by tamping rod

Fig. 8 Cube finishing

Fig.9 Cement concrete cube samples

IV. RESULTS & DISCUSSION

A. Effects of fly ash and nano Silica on Slump Value

In this paper the slump cone test was performed for both ordinary concrete mix and modified concrete mix. In case of modified concrete mix the cement partially replaced by fixed quantity of 20 % fly-ash by weight of cement and varying quantity of nano-silica 0.3%, 0.5%, 0.75% and 1% by weight of cement for both grades of concrete M20 and M30. Slump values are given in Table 10 and 11 for M20 and M30 grades of concrete respectively. The experimental procedure is shown in figure 10.

Fig.10 Slump test

It is seen that for M25 grade of concrete upto NS 0.5 % slump value increases and on further increasing NS beyond 0.5% slump value start decreasing .And for M30 grade of concrete upto NS 0.3% slump value increases and on further increasing NS beyond 0.3% slump value start decreasing.

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Table 10 Slump values for M20 Grade

S.No.	Material Composition	Slump (mm)
1	Ordinary Concrete	77
2	NS 0.3%& FA 20%	79
3	NS 0.5%& FA 20%	84.5
4	NS 0.75%& FA 20%	69
5	NS 1%& FA 20%	53

Table 11 Slump values for M30 Grade

S. No.	Material Composition	Slump (mm)
1	Ordinary Concrete	69
2	NS 0.3%& FA 20%	72
3	NS 0.5%& FA 20%	67.5
4	NS 0.75%& FA 20%	58
5	NS 1%& FA 20%	46.4

B. Effects of fly ash and nano silica on compressive strength

Compressive strength test was conducted on the test samples prepared using ordinary cement concrete and modified cement concrete (for M20 and M30 grades of concrete). The test results are compared and given in the Tables 12&13 respectively. The experimental procedure is shown in Figures 11.

Fig.11. Testing of Cubes

Table 12 Comparison of compressive strength for M20 Grade concrete with 20% fly ash and varied percentage of Nano silica (0.3 to 1%)

Period (in days)	Compressive strength of ordinary concrete	Compressive strength (in MPa) of modified concrete			
		20% FA and 0.3% NS	20% FA and 0.5% NS	20% FA and 0.75% NS	20% FA and 1% NS
7 Days	15.06	16.21	18.04	20.76	18.07
28 Days	24.88	25.23	26.25	27.11	25.41
% increase in 7 days strength		7.64%	19.78%	37.84%	19.98%
% increase in 28 days strength		1.41%	5.51%	8.96%	2.2%

*NS: Nano Silica *FA: Fly-Ash

From the above table it can be seen that the compressive strength increases linearly with the increased percentage of nano-silica up to 0.75% after that compressive strength is getting reduced.

The maximum compressive strength is obtained as 27.11 MPa with 20% of flyash and 0.75% of nano-silicaby weight of cement. The strength found to be 20.76 MPa and 27.11 MPa for 7 days and 28 days respectively for M20 grade of modified concrete. The compressive strength of ordinary concrete comes out to be 15.06 MPa and 24.88 MPa for 7 days and 28 days respectively. Hence the maximum percentage increase in the compressive strength comes out to be 8.96 % for M20 grade of concrete in 28 days. Compressive strength of five types of specimen for 7 days and 28 days is also shown in Figures 12 to 15.

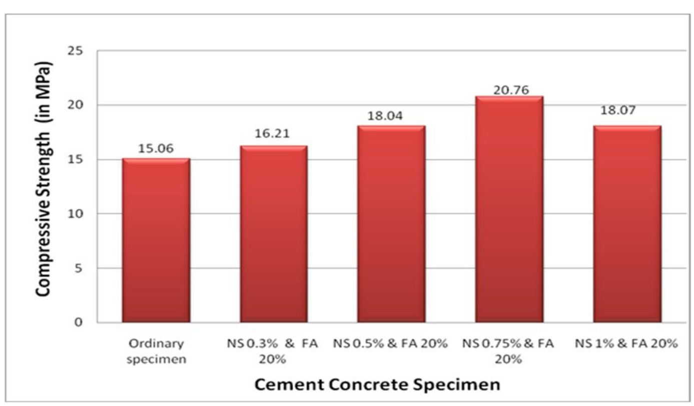

Fig. 12. Compressive strength for M20 grade of concrete at 7 days

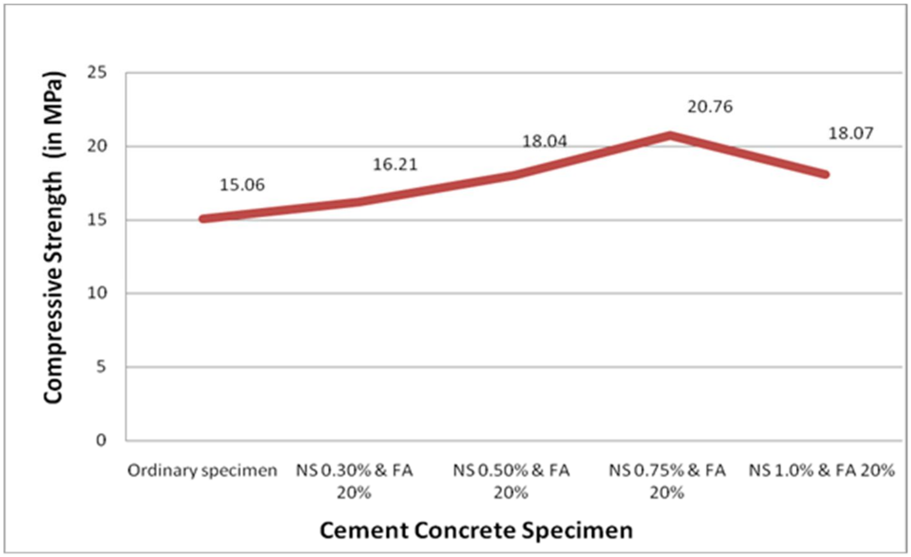

Fig. 13. Graph representing 7 day compressive strength for M20 grade concrete

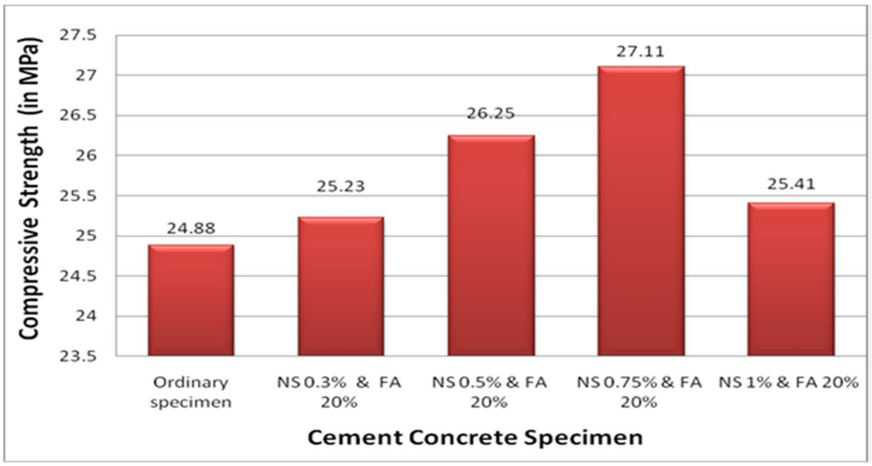

Fig.14. 28 Days compressive strength for M20 grade concrete

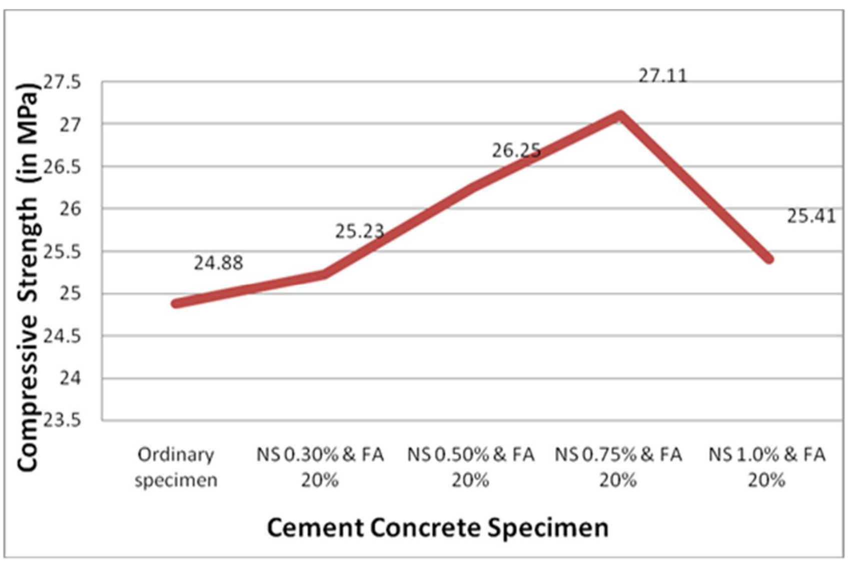

Fig.15. Graph representing 28 days compressive strength for M20 grade concrete

Table 13 Comparison of compressive strength for M30 grade concrete with 20% of fly ash varied percentage of Nano-silica

Period (in days)	Compressive strength of ordinary concrete	Compressive strength (in MPa) of modified Concrete			
		20% FA and 0.3% NS	20% FA and 0.5% NS	20% FA and 0.75% NS	20% FA and 1% NS
7 Days	23.17	23.92	26.01	31.73	26.29
28 Days	34.91	35.64	36.48	40.10	35.41
% increase in 7 days strength		3.24%	12.25%	36.95%	13.47%
% increase in 28 days strength		2.09%	4.5%	14.86%	1.44%

*NS: Nano Silica *FA: Fly Ash

From the above table it can be seen that for the compressive strength increases linearly with the increased percentage of nanosilica up to 0.75% after that compressive strength is getting reduced.

In the Figure 23, it can be seen that the microstructure is too dense and large crystalline lumps can be observed. These lumps indicate the agglomeration of fly Ash and nano Silica particles which forms the structure crystalline and hence increases the strength.

In the Figure 24, it can be seen that the microstructure looks less dense and it is observed that on increasing nano-silica more than 0.75% less C-S-H gel is produced. Hence optimum dose of nano-silica is 0.75% along with 20% fly-ash on which maximum strength of cement concrete specimen is observed.

The maximum compressive strength is obtained with 20% of fly-ash and 0.75% of nano-silica by weight of cement. The compressive strength found to be 31.73 MPa and 40.10 MPa for 7 days and 28 days respectively for M30 grade of modified concrete. The compressive strength of ordinary concrete comes out to be 23.17 MPa and 34.91 MPa for 7 day and 28 days respectively. Hence the maximum percentage increase in the compressive strength comes out to be 14.86 for M30 grade of concrete in 28 days. Compressive strength of five types of concrete specimen for 7 days and 28 days is also shown in Figures 16 to 19.

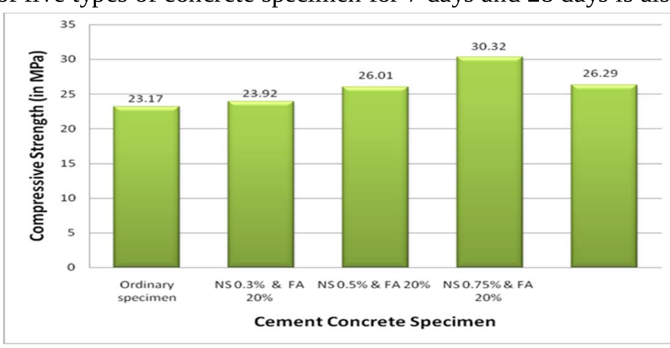

Fig. 16. 7 days compressive strength for M30 grade concrete

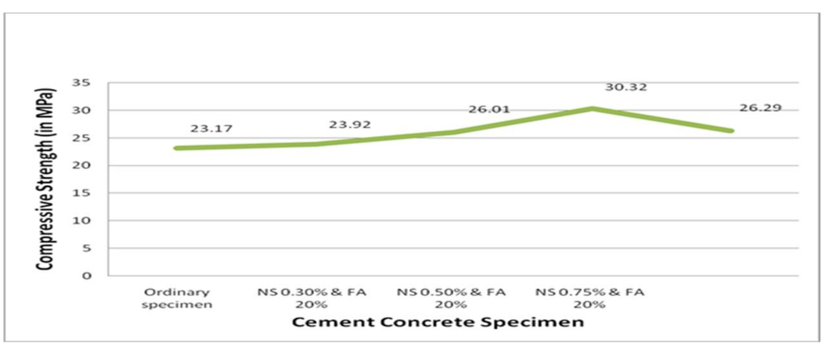

Fig.17. Graph representing 7 day compressive strength for M30 grade

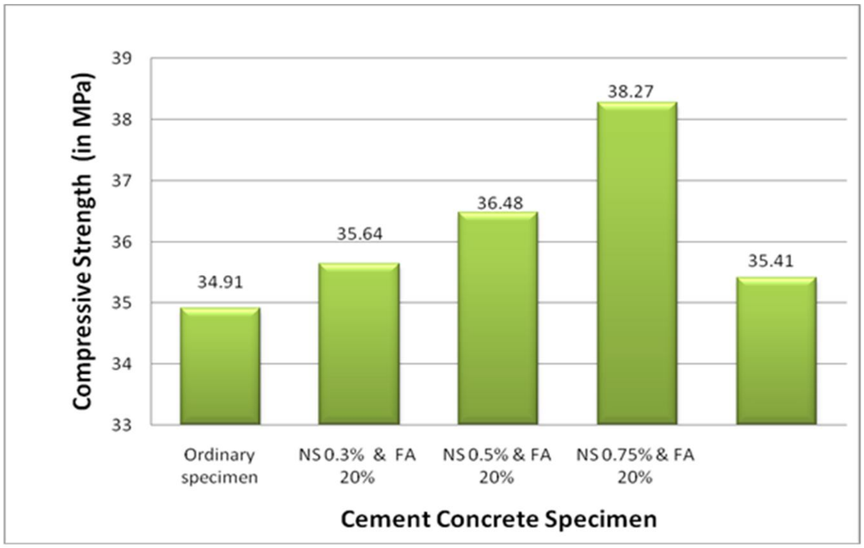

Fig.18. Compressive strength for M30 Grade of five types of concrete samples at 28 days

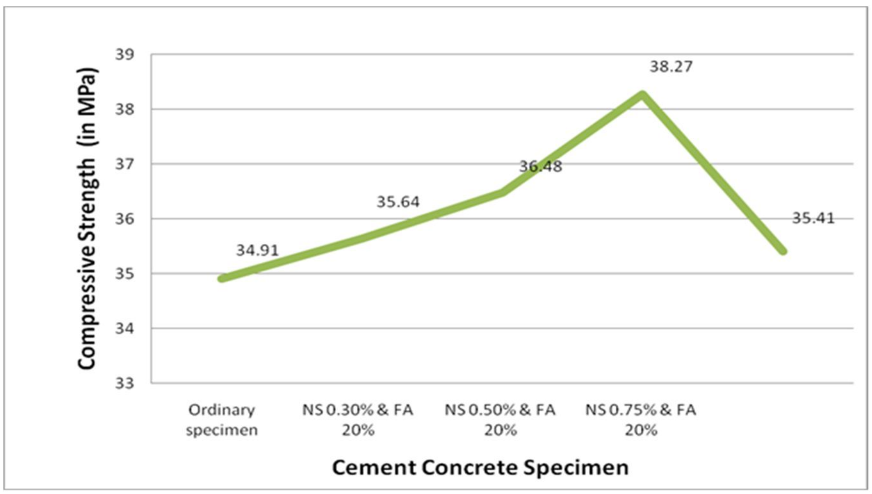

Fig.19. Graph representing 7 day compressive strength for M30

C. Microstructure Analysis of Cement Concrete Specimens Using Field Emission Scanning Electron Microscope (FESEM)

Microscopic images were captured using FESEM of the test samples prepared with ordinary cement concrete and modified cement concrete. Microscopic images are shown in Figure 20 to 24.

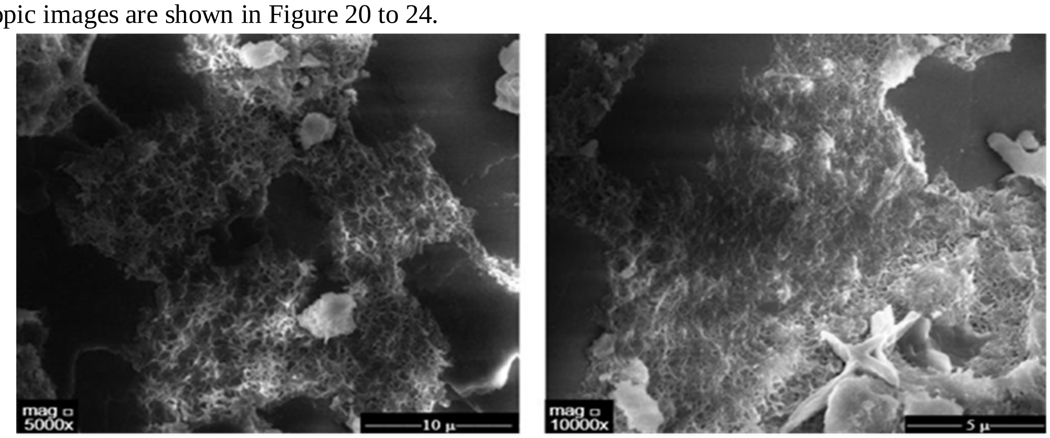

Fig.20. FESEM Micro image of ordinary cement concrete sample with Different magnifications

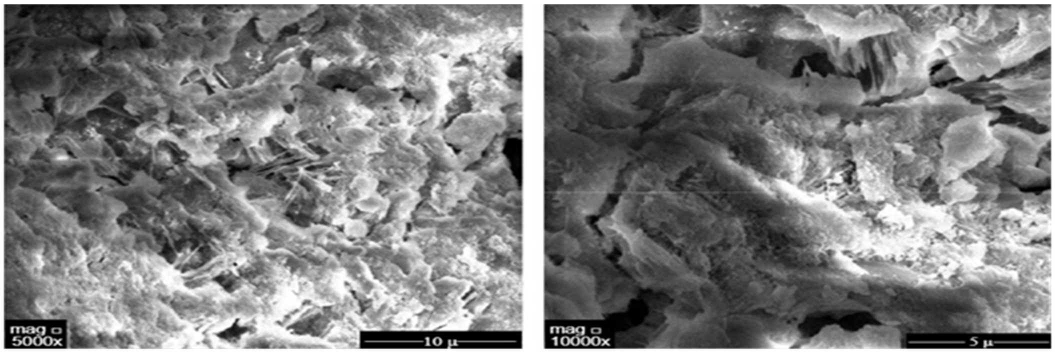

Fig. 21. FESEM micro images of sample with 20% fly-ash and 0.3%nano-silica by weight of cement with different magnifications

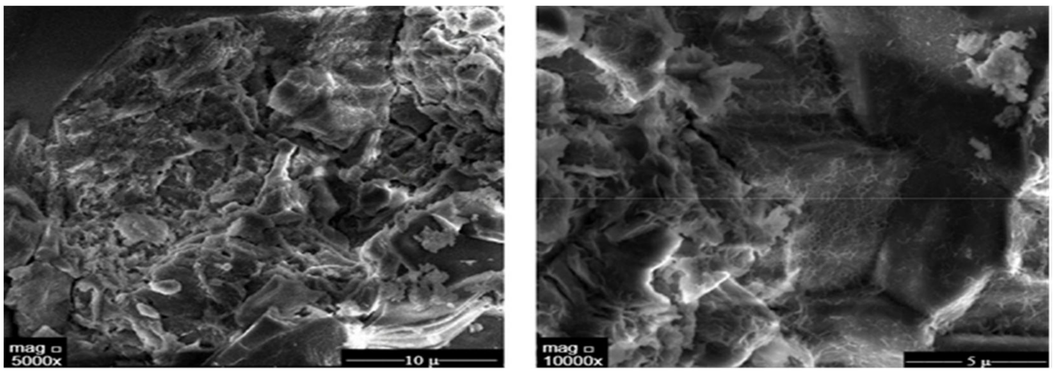

Fig.22. FESEM micro image of sample with 20% fly-ash and 0.5% nano silica by weight of cement with different magnification

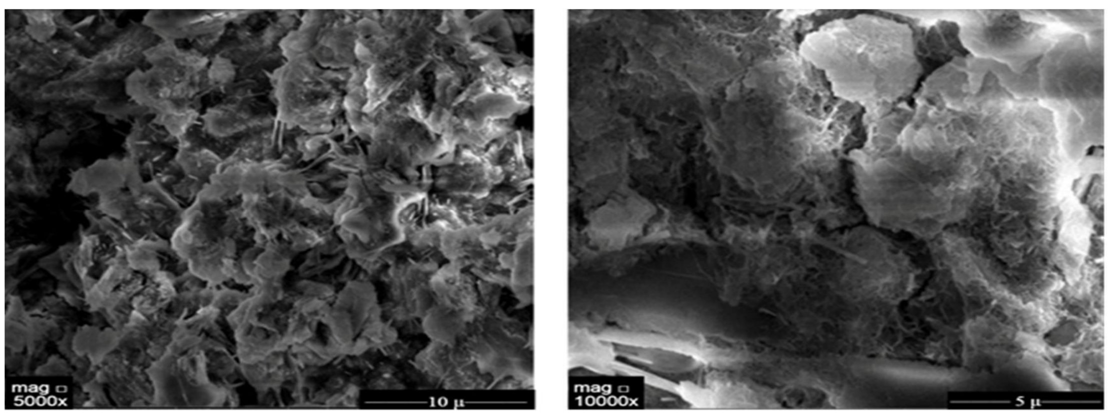

Fig.23. FESEM Micro image of sample with 20% fly-ash and 0.75% nano silica by weight of cement with different magnification

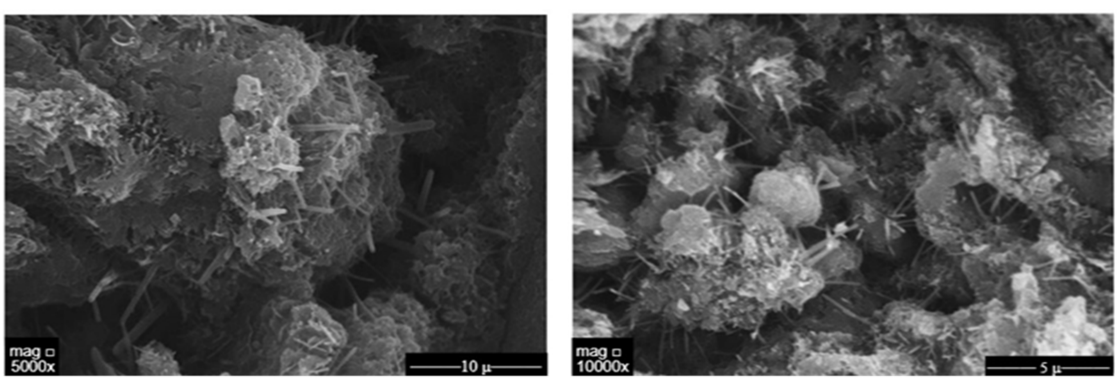

Fig.24. FESEM micro images of sample with 20% fly-ash and 1.0% nano-silica by weight of cement with different magnification

In the Figure 20, it distinctly noticed that the C-S-H gel is dispersed with many voids spaces in between the lumps. The lumps can be consists of $Ca(OH)_2$ which lessen the zone between aggregate and cement paste called as Interfacial Transition Zone (ITZ) hence affecting the strength. The microstructure of the specimen looks to contain mostly amorphous substances.

In the Figure 21, we can see a better packed microstructure but again large lumps of possibly $Ca(OH)_2$ crystals surrounded connected by needle like structures are found which is generally seen in plain concrete. The nano-silica and fly-ash particles occupying the pores in C-S-H gel gives the compact structure but is not sufficient in amount to react with $Ca(OH)_2$ and produce C-S-H gel.

In the Figure 22, a uniform microstructure with very little void can be seen. The absence of $Ca(OH)_2$ crystals indicates that nano-silica and fly-ash has reacted with $Ca\ (OH)_2$ and converted it into C-S-H gel.

In the Figure 23, it can be seen that the microstructure is too dense and large crystalline lumps can be observed. These lumps indicate the agglomeration of fly Ash and nano Silica particles which forms the structure crystalline and hence increases the strength.

In the Figure 24, it can be seen that the microstructure looks less dense and it is observed that on increasing nano-silica more than 0.75% less C-S-H gel is produced. Hence optimum dose of nano-silica is 0.75% along with 20% fly-ash on which maximum strength of cement concrete specimen is observed.

V. CONCLUSIONS

From the test results obtained from the experimental investigations, following conclusions can be drawn.

1) Increase in the compressive strength for both the type of concrete mix (M20 and M30 grades) with the increased percentage of nano-silica up to 0.75% and fly-ash 20% by weight of cement and then strength is getting reduced with the increased percentage of nano-silica. The maximum 28 days strength of modified concrete is obtained as 27 MPa and 40 MPa for M20 and M30 grades of concrete respectively with nano-silica of 0.75% and 20% of fly-ash by weight of the cement.
2) Workability of concrete increases on addition of small percentage of nano-silica whereas workability starts decreasing with the increased percentage of nano-silica.
3) It is observed that on addition of nano-silica there is considerable increase in 7 days strength of cement concrete mix compared to 28 day`s increase in strength.
4) Microstructure of the concrete specimens becoming dense on addition of nano-silica.

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