International Journal of Current Advanced Research
ISSN: O: 2319-6475, ISSN: P: 2319-6505, Impact Factor: SJIF: 5.995
Available Online at www.journalijcar.org
Volume 6; Issue 11; November 2017; Page No. 7754-7758
DOI: http://dx.doi.org/10.24327/ijcar.2017.7758.1220

Research Article

EFFECT OF NANO-SILICA AND FLY ASH ON COMPRESSIVE STRENGTH OF HARDENED CEMENT MORTAR

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A R T I C L E I N F O

Article History:
Received 16th August, 2017
Received in revised form 25th September, 2017
Accepted 3rd October, 2017
Published online 28th November, 2017

Key words:
Nano Silica (NS), Fly ash(FA), Compressive strength, Regression model, SEM analysis.

A B S T R A C T

This paper presenting the effect of nano silica and fly ash on compressive strength of cement mortar. The nano silica (size of particle is 17nano meters) content is varied from 0 to 4% with increment of 1%. The fly ash is also taken as pozzolona material for cement mortar and this is taken in to the mix as replacement to the cement. The fly ash is varied in the proportion of 0,10,20,30 and 40% in the cement mortar mix along with nano silica. The cement mortar cubes are tested at 3, 14, 28 and 56 days to evaluate the compressive strength. The results are revealed that, the mix with nano silica and fly ash is effective at 1% and 20% respectively. The effectiveness of nano silica for the fly ash cement mortar is noticed at and after 28th day of compressive strength. The regression model is developed to assess the compressive strength of mortar as function of %of nano silica and fly ash. To support the compressive strength of cement mortar SEM analysis is performed.

INTRODUCTION

The principal purpose of mortar is to adhesively bind together the individual masonry units. It also provides protection against the penetration of air and water through the joints in a masonry assembly. Mortar also bonds the non-masonry elements of an assembly such as joint reinforcement and ties. It also compensates for minor dimensional variations in the masonry units and provides coursing adjustment to meet required dimensions. Finally, mortar joints contribute to the architectural quality of the masonry assembly both through colour and shadow. Ancient Egyptian mortars were made from burned gypsum and sand while later development in mortar technology utilized a combination of lime and sand. These mortars developed their strength slowly. Since about 1900, Portland cement has been incorporated into mortar to provide more rapid strength development. Modern mortar is composed of cement and lime or masonry/mortar cements, masonry sand, water, and possibly some admixtures. The use of nano materials in the construction sector is gaining wide spread attention as significant improvements are expected to be achieved in the desired properties of construction materials. The present study is planned to evaluate the compressive strength of mortar with use of nano silica and fly ash. The nano silica is added to the mix and the fly ash is used in the mix as replacement to cement.

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The detailed exprememtal work is presenting in the next section. The review of literature is presenting below to know the status of work in this arena.

Ye Qing *et.al*, (2005) studied the influence of nano silica addition on properties of hardened cement paste. The results presenting that the influence of nano-silica (NS) with the addition on properties of hardened cement paste (hcp) as compared with the silica fume.Byung-Wanjo *et.al*,(2007) studied the characteristics of cement mortar with nano silica particles. The study represents the amorphous or glassy silica which as the major component of the pozzolan, which reacts with CaOH formed from calcium silicate hydration. Quercia.G *et.al*, (2010) studied the effect of silica fines as additive to the concrete mixtures. The results are represents the method to reduce the cement content in the concrete mixes with the use of silica fines. This is the one of the silica fines with high potential as cement replacement as the concrete additive is nano silica. Tobon.J.I. *et al*,(2010) studied the performance of Portland cement blended with nano silica and silica fume. The study focused to find the properties of normal consistency, fluidity, setting times, heat of hydration and compressive strength on mortars and pastes. Land.G *et.al*, (2011), presented the nucleation seeding approach to control the kinetic of cement hydration in the process of nano-silica (NS) by adding to the cement paste. Reddy Babu.G (2013) conducted experimental work to estimate the properties of blended cement with nano-SiO_2 (NS). The study showed that, the silica noticed as the major component of a pozzolan, reacts with calcium hydroxide formed from calcium silicates hydration.

The rate of Pozzolonic reaction is proportional to the amount of surface area available for reaction. Sayed *et. al,* (2013) carried the experiment work to find Influence of nano- silica addition on properties of fresh and hardened cement mortar.The main aim of the work to investigation of the influence of adding nano-silica particles, on the properties of fresh and hardened cement mortar through measurements of compressive and workability and flexure strengths in addition to measuring by SEM analysis. Kartikeyan.*et.al*. (2014) carried experimental investigations on using nano-sized (Nano-silica) mineral admixtures in concrete as a partial replacement of cement by weight. The silica fume (SF) which is the mineral admixture used in this work was ground for one hour with varying quantities using planetary ball mill. On understanding and analyze the results of grinding, it was observed that the grinding was effective in one hour and the size of micro-silica (10^{-6}) has reduced by 75.45% reaching nano size. Lok pratap singh *et.al*, (2015) did the work to know the effect of morphology and dispensability of silica nano particles on the mechanical behavior of cement mortar. The influence of powered and colloidal nano-silica (NS) on the mechanical properties of cement mortar has been investigated in this study. The use of nano materials in the construction sector is gaining widespread attention as significant improvements are expected to be achieved in the desired properties of construction materials. Dariush Hajizadehasl (2016) reviewed the use Nanosilica in production of concrete in order to improve its mechanical properties and durability. Pawel Sikoraa *et.al*,(2017) evaluated the possibility of manufacturing sustainable cement mortars with the use of nano silica and brown soda lime waste glass as fine aggregate. In their study, they studied the mechanical and thermal properties of cement mortar.

From the above review of literature it is noticed that, few works are taken on nano silica along with the admixtures. No work has been noticed to estimate the compressive strength of cement mortar with additive and replacement of nano silica and flyash respectively. Hence the experimental work has planned to evaluate the compressive strength. The work has been carried in two stages. At first stage the nano silica effect is studied on Ordinary Portland cement (OPC). In the second stage the mix is prepared with fly ash along with nano silica.Total 100 mixes are taken for the experimental work and for each mix three cubes are cast and tested in the laboratory. The detailed experimental programme is presenting below.

Experimental Programme

The following factors are taken for experimental work.

Sl.No	Factors for the experimental work	
1	Nano Silica variation in the mix as additive	0,1,2,3 and 4% by weight of cement
2	Fly ash variation as replacement to cement	0, 10, 20, 30 and 40% by weight of cement
3	Mix proportion	1:3 (Cement: Sand)
4	Water cement ration for the each mix	[(Percentage of water for standard consistency /4)+3.0] x[% of the weight of the aggregate].
5	Size of cube	70.6 x 70.6 x 70.6mm
6	Total number of mixes	100
7	Total number of cubes	300
8	Strength evaluated at	3rd , 14th , 28th and 56th day.

MATERIALS

The following materials are used for the experimental work

Cement

Ordinary Portland cement (Grade 53) was used. The specific gravity of cement found as 3.12 and the initial and finial setting times are noticed as 29 and 610 minutes respectively.

Water

Portable water was used for mixing and curing of specimens.

Fine Aggregate

Ennore sand was used for the work and the sand was taken in three grades of fine, medium and coarse as specified in the Indian Standard Sand IS650:1991. The used grades of sand can be viewed in the figure 1

Fig 1 Ennore sand

Nano Silica: Nano silica was brought form the suppliers of Astrra Chemicals, Chennai,Tamil Nadu(State). The size particle was noticed as 17nano meters and it is in powder form. The SiO_2 content is about 99.8% in the nano silica. The used nano silica can be viewed in the figure 2(a).

FlyAsh (FA): The fly ash was obtained from Rayalasema Thermal Power Project (RTPP), Muddanur in Kadapa (District), Andhra Pradesh (State). The specific gravity of fly ash is 2.2. The used fly ash can be observed in figure 2(b)

Fig 2 a Nano Silica (NS)

Fig 2 b Fly Ash (FA)

Casting and Testing

The required quantities of materials are weighted for each mix and kept separately. For each mix the cement sand proportion taken as 1:3. The water content is taken for the mix with the help of normal consistency of the cement paste. The mix was prepared and the cement mortar is placed in the cubes and compaction was provided by using mortar vibrator. The specimens are taken out after 24 hours and then placed in the curing pond for 28 days. Later the specimens are tested in the compression testing machine. The loading was applied with stress control of 35MPa/min till failure of the specimen. The final reading in the machine is taken as ultimate or failure load. Average of three cube specimens was taken as strength of the mix and the obtained results are presented in the discussion of test results. The testing of cube and tested samples can be viewed in figure 3 and figure 4.

Fig 3 Testing of cube specimen

Fig 4 Tested Specimens

TEST RESULTS AND DISCUSSION

Compressive Strength

The obtained 3, 14, 28 and 56 days cube compressive strength results for various mixes are presented in Table 1. From the results, it is noticed that, the compressive strengths for nano silica addition for cement mortar mix shown higher values at 1% for various days of 3, 14, 28 and 56. If strength are compared among the various % of addition of nano silica, at 1% and 2% shown higher values when compared with the mix without nano silica (0% nano silica) and for other dosage of mixes (3 and 4% nano silica) the strengths are not so effective. For 28 days, with nano silica at 1 and 2% shown the strengths about 16.41 and 7.33% higher than the mix without nano silica. The effectiveness of the nano silica for all mixes is depicted in figure 5 in the form of bar chart. From this it is observed that as the day's increases for all mixes the strengths are increasing. The increasing in strength may due to participation of nano silica in chemical reaction with residual calcium hydroxide of cement.

The compressive strength results of mixes with nano silica and fly ash are presented in Table 1 and figure 6 to 9. In these results also the nano silica was shown superior performance at 1%. The effective replacement for the mix with fly ash is 20%. From the figure 6 to 9, it is observed that at initial days (i.e., 3 to 14 days) the nano silica cannot show any effectiveness to enhance the strength of the mix. But at later stages of i.e., at and after 28 days the nano silica effect was noticed and the strength enhancement was noticed when compared with the mix of fly ash only (0%nano silica). The effectiveness is more for the 1,2 and 3% of nano silica but is less for 4% nano silica. Among the various % of nano silica the 1% nano silica showed more strength values than others. The nano silica may participate along with the fly ash in cement in the chemical reaction with the calcium hydroxide and may also the nano silica can act as infill between cement particles. In general for denser mixes either for mortar or concretes, the strength are increases, same reason may be applicable herein for shown higher strength values. To support the results Scanning Electron Microscope (SEM) was performed for the mix of 1% nano silica (NS) and 20% fly ash(FA) and for the mix of 0% nano silica and 20% fly ash. The obtained images are presented in figure 10 and11, from those it is observed that the nano silica mix along with fly ash (1%NS+20%FA) shown very uniform dispersion of C-S-H gel texture but the mix without nano silica and with fly ash (0%NS+20%FA) shown porous texture(black spots) for test sample.

Table 1 Cube Compressive strength

Mix	Proportions for Ordinary Portland Cement(OPC)	Nomenclature	Compressive Strength (MPa)			
			3 days	14 days	28 days	56 days
1	0% Nano silica	0%NA	26.23	37.23	41.06	46.89
2	1% Nano silica	1%NA	29.36	41.65	47.80	54.75
3	2% Nano silica	2%NA	27.13	40.98	44.07	49.13
4	3% Nano silica	3%NA	23.38	39.15	42.63	44.23
5	4% Nano silica	4%NA	19.80	32.40	35.50	37.60
6	0% nano silica 10% fly ash	0%NA+10%FA	25.05	28.00	29.74	37.86
7	0% nano silica 20% fly ash	0%NA+20%FA	32.65	37.23	39.00	43.96
8	0% nano silica 30% fly ash	0%NA+30%FA	21.79	25.79	28.87	34.73
9	0% nanosilica 40% fly ash	0%NA+40%FA	19.83	23.26	27.63	30.13
10	1% nano silica 10% fly ash	1%NA+10%FA	15.46	31.00	50.14	54.25
11	1% nano silica 20% fly ash	1%NA+20%FA	17.46	28.23	51.72	56.38
12	1% nano silica 30% fly ash	1%NA+30%FA	12.60	23.63	47.66	50.69
13	1% nanosilica 40% fly ash	1%NA+40%FA	11.03	20.63	44.38	46.76
14	2% nano silica 10% fly ash	2%NA+10%FA	14.80	33.53	48.65	52.89
15	2% nano silica 20% fly ash	2%NA+20%FA	15.96	29.23	50.73	54.12
16	2% nano silica 30% fly ash	2%NA+30%FA	13.16	27.36	46.12	52.43
17	2% nanosilica 40% fly ash	2%NA+40%FA	12.35	25.63	44.65	47.79
18	3% nano silica 10% fly ash	3%NA+10%FA	13.53	27.06	46.07	51.17
19	3% nano silica 20% fly ash	3%NA+20%FA	14.83	26.63	44.73	49.21
20	3% nano silica 30% fly ash	3%NA+30%FA	12.86	23.80	42.05	45.61
21	3% nanosilica 40% fly ash	3%NA+40%FA	10.36	22.10	40.36	43.72
22	4% nano silica 10% fly ash	4%NA+10%FA	08.70	15.76	23.78	37.52
23	4% nano silica 20% fly ash	4%NA+20%FA	05.16	14.13	21.63	33.15
24	4% nano silica 30% fly ash	4%NA+30%FA	04.90	12.23	19.03	31.62
25	4% nanosilica 40% fly ash	4%NA+40%FA	04.40	10.66	15.46	28.57

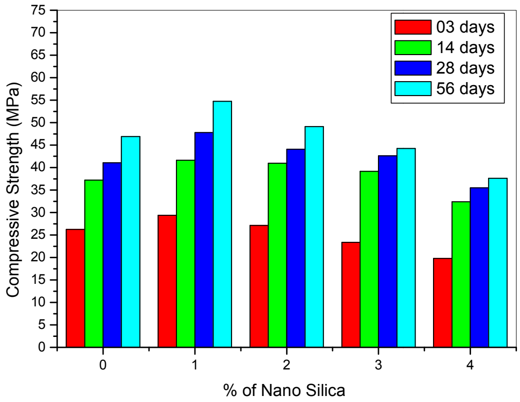

Fig 5 Compressive strength vs Nano Silica

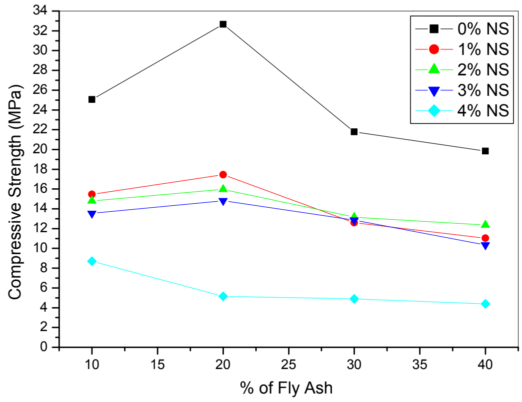

Fig 6 3 day's Compressive strength

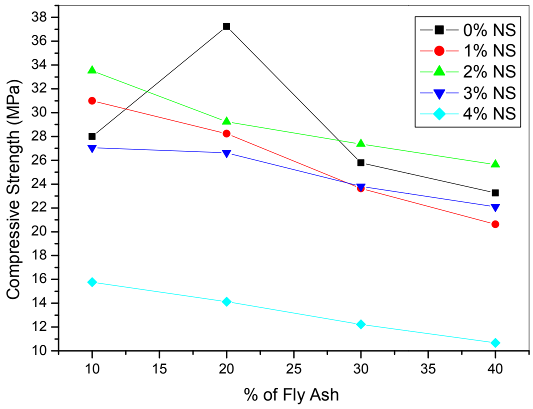

Fig 7 14 day's Compressive strength

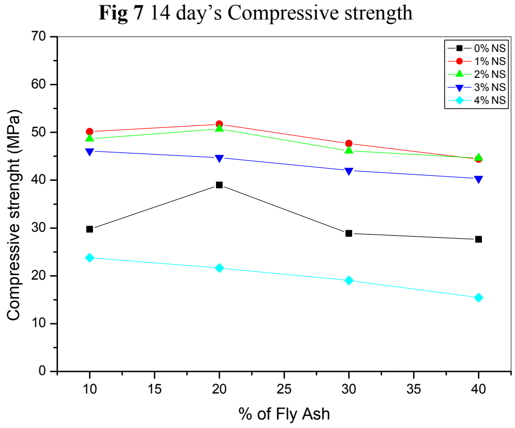

Fig 8 28 day's Compressive strength

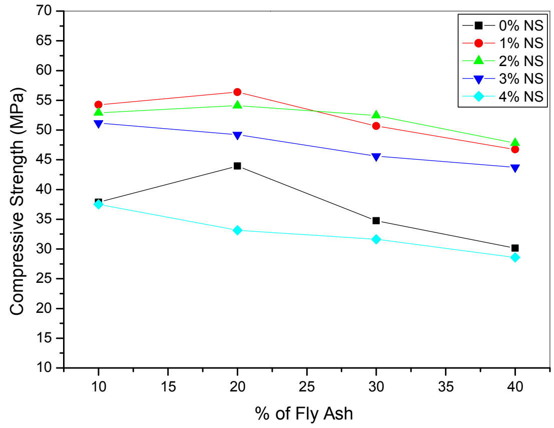

Fig 9 56 day's Compressive strength

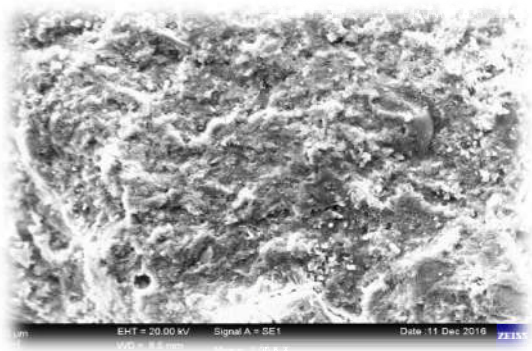

Fig 10 SEM image for 1%NS+20%FA

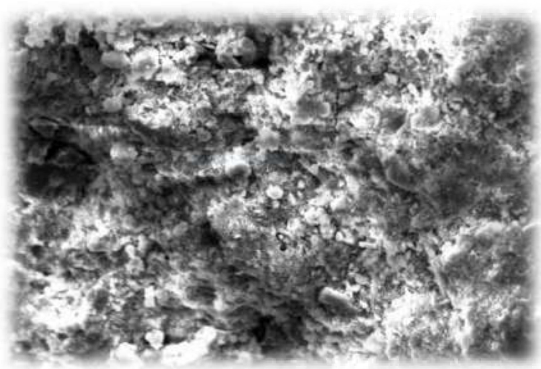

Fig 11 SEM image for 0%NS+20%FA

Relation between Compressive Strength, % NS and % FA:

The authors would like to develop a simple regression model to assess the 28 days of compressive strength of cement mortar results. From the above section it is noticed that, the NS is effective at 1 and 2% of NS along with fly ash. Hence herein the model was developed in such way that, it is applicable for those two effective percentages of NS. The performance of the model is also tested and from the results it is found that the ratio between EXP/RM is about is varying 0.96 to 1.05. This inferences result are varying about ± 5% and came to know that, the proposed equation is shown good compatibility for the experimental results.

f_{cm} = 54.15- 0.94(%NS) - 0.20(%FA) --------------(1)

Subjected to constraints

$1\% \leq NS \leq 2\ \%$ ------------------(2)

$10\% \leq NS \leq 40\ \%$ ------------------(3)

In the above equations

f_{cm} = 28 days cube compressive strength of mortar in MPa
NS=Nano Silica in percentage
FA= Fly Ash in percentage

Table 2 Performance of Regression Model

Nomenclature	Experimental(EXP) cube compressive strength(MPa)	Regression Model(RM) cube compressive strength(MPa)	EXP / RM
1%NS+10%FA	50.14	51.21	0.97
1%NS+20%FA	51.72	49.21	1.05
1%NS+30%FA	47.66	47.21	1.00
1%NS+40%FA	44.38	45.21	0.98
2%NS+10%FA	48.65	50.27	0.96
2%NS+20%FA	50.73	48.27	1.05
2%NS+30%FA	46.12	46.27	0.99
2%NS+40%FA	44.65	44.27	1.00

CONCLUSIONS

The following conclusions are drawn from the present experimental work.

1. The compressive strengths are effective at 1% of NS for all mixes.
2. For 1%NS at 28 and 56 days the cube compressive strength is higher about 16% when compared with 0% NS mix.
3. The mix with various proportions of fly ash content is effective at 20% of FA
4. The mixes with NS and FA is effective at 1% NS and 20%FA and the % is increase in 28 compressive strength is about 32% when compared with 0% NS and 20% FA
5. In over view the best utilization of NS for fly ash mixes is 1 and 2% of NS, because the variation between them is very marginal.
6. To estimate the cube compressive strength results, proposed regression model in this article is made good agreement with the experimental results.

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How to cite this article:

Naresh Kumar T *et al* (2017) 'Effect of Nano-Silica And Fly Ash on Compressive Strength of Hardened Cement Mortar', *International Journal of Current Advanced Research,* 06(11), pp. 7754-7758.
DOI: http://dx.doi.org/10.24327/ijcar.2017.7758.1220

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