

Effect of Nano Silica on Mechanical Properties of Concrete



Younus Akram Ganie, Brahmjeet Singh, Sandeep Singla, Sandeep Kumar

Abstract: Nano materials are undoubtedly one of the versatile materials whose properties hasn't been much explored yet. Regular efforts are being made to perk up the quality of concrete on various fronts to make it more sustainable. In this work, Nano-silica (Sio₂) has been selected to induce it in M30 base mix design and workability test and strength tests has been selected which will be carried out on cube and beam specimens casted and cured for seven, fourteen and twenty eight days of duration. Properties of OPC and nano Silica powder has been note down. Nano silica comes in different surface sizes in market i.e. 50 m²/g, 250 m²/g and 500 m²/g. Current study chose Sio₂ having 250 m²/g surface area as was available in local market. Concrete mixes are designed by taking 0.5%, 1%, 1.5% and 2% of Nano-silica with respect to weight of cement. The addition of nano silica proved to be beneficial to the mechanical properties which increased significantly than the base mix. Also workability test showed moderate values of slump which also decreases when Nano-silica proportion is increased.

Keywords: Compressive Strength, Flexural Strength, Nano Silica, Workability

I. INTRODUCTION

Nanomaterial, being such a versatile and multifaceted stuff, much heed hasn't been paid to its all in all properties which can be of appreciable significance. In addition to this, it has a notable role in slashing the impact on environment, tweaking safety and truncate the costs coupled with civil framework. Till now, nano alumina, nano silica and nano carbon tubes have been capaciously explored since years all because of their multifaceted properties used in reinforcing the properties of the materials. The complexity of concrete lies in the behavior of its constituents. It is well established that the hydration of concrete is a complex mechanism, which is not completely understood. The use of nano materials in the universal building material i.e. concrete is what this research is all about. The unexampled properties of nano silica have been investigated in this work to establish a relation between proportion of nano silica used and improvement in the properties.

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In this work M30 has been used to investigate the efficient parameters on which the use of concrete is based. The tests have been conducted on the set parameters to arrive at the true and reliable results.

The codal provisions have been followed in designing the mix. The overall effect of nano silica on the concrete mix can be attributed to its nano size which has a large effect in reinforcing the properties of the binder. Various dosages of the nano silica have been used (at various %ages w.r.t. weight of cement) and slump, flexural and compressive strength tests have been conducted to arrive at the results. Also, tests have been conducted at regular intervals to examine the trends. Finally, the results have been scrutinized and compared with that of base mix to check the performance of the various percentages of nano silica added to the mix.

II. LITERATURE SURVEY

The complexity of concrete lies in the behavior of its constituents. It is well established that the hydration of concrete is a complex mechanism, which is not completely understood. The use of nano materials in the universal building material i.e. concrete is what this research is all about. The unexampled properties of nano silica have been investigated in this work to establish a relation between proportion of nano silica used and improvement in the properties. Inferences have been drawn from the previous work done by various researchers. A few of them are mentioned here.

Ji et al Tao (2018) [11], in his work presented the resistant behavior of concrete to permeability of water. Nano silica was used in the study to check its behavioral effect on the resistance to water. The study demonstrated that the behavior improved the resistance quite significantly while also improving its microstructure due to the minute structure of the material. Needless to mention that the void blocking ability of nano silica helped to improve the said properties and overall structure of the concrete.

Ozyhldierem Celyk et al (2017) [6], in his research work also compared the properties of concrete containing common supplementary cementing materials with that of concrete containing various nano materials. The improvement in the concrete containing nano materials was observed due to the fact that the complex process of hydration gets accelerated due to addition of various nano materials. Different improvements were seen by using different nano materials with different amounts. Nano alumina and nano clay were used in the study and properties of concrete containing common supplementary cementing materials were compared with the same.

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III. OBJECTIVES

Following objectives are set to evaluate the outcome results-

1. To scrutinize the influence of nano silica on mechanical properties and workability of concrete.
2. To add nano silica to concrete mix in various percentages w.r.t. weight of cement.
3. To determine the compressive and flexural strength at seven, fourteen and twenty eight days and workability of the concrete using slump test.
4. To compare the results obtained in various tests with and without nano silica content.

IV. RESEARCH METHODOLOGY

1. To collect Nano-silica powder having surface area of about 250 m²/g along with other materials needed for casting and curing processes.
2. To evaluate various properties of cement and aggregates like specific gravity, fineness, sieve analysis etc.
3. To prepare different cube and beam specimens by varying the percentage of nano-silica in concrete mix.
4. To carry out different tests on the prepared specimens' i.e. compressive strength, flexural strength and slump test.
5. To compare and evaluate the results obtained in various tests performed on plain concrete and concrete containing nano silica.

M30 concrete was used in the present work.

V. RESULTS

M30 concrete mix design is used in present study. Six samples are casted in base mix design in which base mix design first (0%) and 0.25%, 0.5 %, 1%, 1.5% and 2% weight of nano silica has been used w.r.t to weight of cement. Water to cement ratio of 0.40 was taken. The names given to all six mixes are shown in table 1:

Table 1: Names given to six mixes with different %ages of nano silica.

%age of Nano-silica w.r.t cement weight	Name of concrete mix
0.00%	M30
0.25%	MNS.25
0.50%	MNS.5
1.00%	MNS1
1.50%	MNS1.5
2.00%	MNS2.0

A. Workability Test Results.

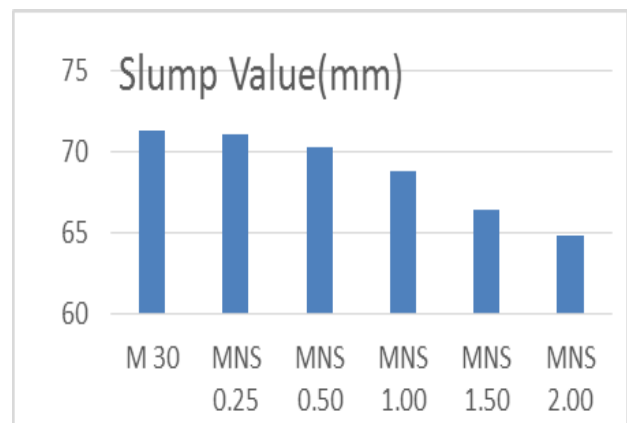
Slump test has been used to determine workability of various mixes. For w/c = 0.40, 71.3 mm of slump was observed in base concrete made with 0% of Nano silica. The test showed that there's a reduction in the slump value which can be assumed to be because of the high specific surface area of

nano silica. As the percentage of nano silica increased, workability also decreased in the same proportion. Neither too harsh nor too much workable plastic concrete is desired. Several NS doses were given at various percentages to arrive at the results.

The results of concrete slump test are shown in below Table 2:

Table 2: Slump Value of mixes containing different %ages of nano silica.

%weight of Nano-silica w.r.t. weight of cement	Mix design used	Slump value in (mm)
0.00%	M30	71.3
0.25%	MNS.25	71.1
0.50%	MNS.5	70.3
1.00%	MNS1	68.8
1.50%	MNS1.5	66.4
2.00%	MNS2.0	64.8



Graph 1: Showing variation of slump value (in mm) graphically.

Initially, for base mix without any nano silica content, slump of about 71.3 mm was reported. As dosage of nano silica was increased, there was a reduction in slump value gradually which means addition of nano silica reduces the workability in proportion to the %age used. There was about 10% reduction in slump value after the final dosages.

B. Compressive Strength Test Results.

Samples were prepared, cured and examined using Standard Testing Machine (CTM) after 7, 14 and 28 days. It was observed that the compressive strength at 7, 14 and 28 days increased due to addition of NS at different %ages. (Average of 3 values is taken as final value).

Table 3: Values showing Compressive strength obtained after 7, 14 and 28 days after adding different %ages of nano silica.

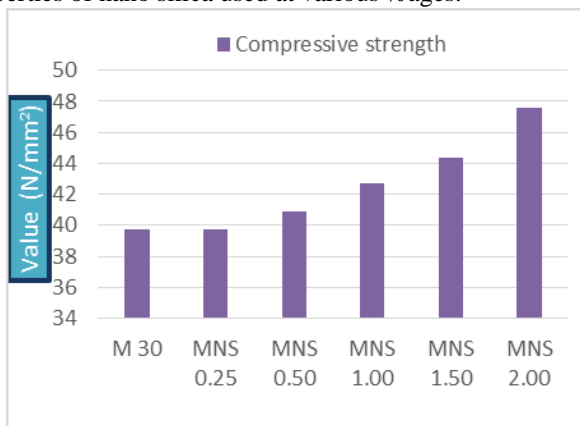
Mix design	Cube No.	Compressive strength (N/mm ²)			
		Sample no.	7 Days	14 days	28 days
M30	1		24.87	28.21	39.73
	2		24.84	28.19	39.74
	3		24.89	28.22	39.71
MNS.25	1		24.97	28.33	39.8
	2		25.01	28.3	39.79
	3		24.99	28.29	39.76
MNS.5	1		25.11	28.42	40.87
	2		25.13	28.44	40.86
	3		25.17	28.39	40.9
MNS1	1		25.34	28.57	42.75
	2		25.37	28.64	42.71
	3		25.42	28.81	42.76
MNS1.5	1		25.73	29.28	44.25
	2		25.71	29.26	44.51
	3		25.76	29.49	44.37
MNS2.0	1		26.75	30.67	47.38
	2		26.79	30.84	47.51
	3		26.65	30.77	47.76

With proportional increase in %age of NS, there is about 8% increase of strength in 7 days, about 9% in 14 days and about 19.6% increase in 28 days strength.

About 8% elevation in compressive strength is reported after 7 days after addition of various %ages of nano silica to the M30 mix.

Whereas there's about 20% elevation in the compressive strength after twenty eight days, which can be attributed to the fact that nano silica being ultrafine in nature has the peculiarity of forming dense microstructure which helps in blocking of pores and ends up in enhancing the strength parameters.

Compressive strength being the main parameter to evaluate the performance of any concrete mix, it can be seen that the performance of mix is enhanced as its compressive strength is increased by about 20% attributed to various properties of nano silica used at various %ages.

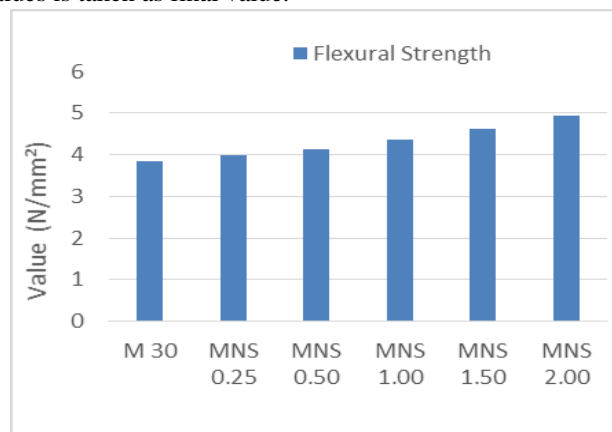


Graph 2: Showing Variation of Compressive Strength after twenty eight days of casting.

C. Flexural Strength Test Results

Flexural strength was performed at the age of 7, 14, and 28 days on 500*100 *100 mm³ beam samples using Flexural Strength Test Machine One of the most important strength parameters needed to validate concrete mix is its flexural strength. Due to presence of silica nanoparticles, the hydration rate is enhanced and more complex microstructure is believed to be formed responsible for the elevation of strength.

As shown in the graph below, the flexural strength also increases as the %age of nano silica is enhanced. (Avg of 3 values is taken as final value.



Graph 3: Showing variation of Flexural Strength after twenty eight days.

As shown in the table below, it can be seen that the flexural strength of concrete increases by about 24.15% after 7 days, by about 18% after 14 days and by about 27.55% after 28 days. The increase in strength of flexural strength is assumed to be because of the fact that the hydration process of concrete gets accelerated by the addition of Nano silica .The main reason being the fact that the surface of Nano silica particles is assumed to act as the nucleation site for the hydration of greater section of cement. Below table shows the values obtained for flexure at different %ages of Nano silica at 7, 14 and 28 days.

Table 4: Values of flexural strength obtained after 7, 14 and 28 days of testing.

Mix design	beam no.	Flexural strength (N/mm ²)		
		7 Days	14 days	28 days
M30	1	2.39	2.79	3.86
	2	2.36	2.73	3.81
	3	2.34	2.77	3.87
MNS.25	1	2.43	2.81	3.97
	2	2.4	2.8	3.96
	3	2.48	2.84	4.04
MNS.5	1	2.57	2.87	4.12
	2	2.5	2.89	4.17

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	3	2.51	2.86	4.09
MNS1	1	2.67	2.97	4.37
	2	2.63	2.96	4.41
	3	2.66	2.93	4.33
MNS1.5	1	2.75	3.12	4.58
	2	2.74	3.17	4.64
	3	2.8	3.11	4.62
MNS2.0	1	2.97	3.23	4.89
	2	2.91	3.31	4.97
	3	2.93	3.26	4.99

VI. CONCLUSION

Current research used the Nano Silica material with M30 concrete mixture to enhance its strength and quality. The research has revealed that the unexampled properties of nano silica have an outstanding effect on the overall performance of M30 mix which confirms its versatile and multifaceted features. On the casted specimens, several tests were done including the compressive, flexural, and slump test. The following inferences can be drawn from the tests performed:-

- Compressive test result showed that the compressive strength of the mix containing different percentages of nano silica has increased considerably. About 8% of compressive strength is increased in 7 days, about 9% in 14 days and about 20% of strength increase is reported in 28 days. This increase is mainly due to exceptional properties of nano silica to form a dense and durable microstructure.
- Flexural test result showed that there's about 24.15% increase in 7 day flexural strength, 18% increase in 14 days and about significant increase of about 27.55% increase in flexural strength in 28 days. Mainly believed to be because of the process of increased rate of hydration due to addition of nano silica content.
- Workability test using Slump Cone showed a decrease in slump of about 10%. Since nano silica helps to increase hydration rate, that's why it has shown a reduction in slump (actually reduction in available water content for paste formation).

Therefore from the above experimentation, it is clear that the addition of nano silica definitely increases the compressive and flexural strength significantly. As the dosage of nano silica content increases, there's subsequent increase in the strength also. Also, slump has also reduced considerably.

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