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Effect of Nano Silica on the Compressive Strength of Concrete

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ABSTRACT

Concrete is one of the most important materials in the construction world. In the present scenario, due to the various industrialization, especially in the urban areas, the demand of construction work increases progressively. Due to which there is very high demand of concrete. So, it is very important to improve the durability and properties of concrete. For this there are various admixtures which are partially replaced with the cement like fly ash, slag, silica fumes, rice husk etc. However, in the present situation, Nano-technology comes as a very faithful approach for improving the strength and durability of the concrete.

In this project, M30 concrete is used and we use Nano-silica of size 236nm as a partial replacement in concrete. Nano-silica enters into the pores of the concrete and sets early due to which the permeability and strength of concrete are improved. An experimental analysis has been done by replacing the cement with Nano silica by increasing its percentage as 0.5%, 1%, 2% and 3% b.w.c. The results show that with increase in amount of Nano-silica, the compressive strength increases up to 3%, however, if amount of Nano-silica goes beyond 3%, the compressive strength of concrete starts decreasing. In these experimental tests, there are 10 cubes prepared with the sample and tested at 7 and 28 days.

KEYWORDS: *Nano-silica, Compressive Strength, UPV test, etc*

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1. INTRODUCTION

In 21st century, due to the construction of various types of structures whether from buildings to factories or from bridges to airports, there is very wide application of concrete. Out of the various materials used for preparing concrete, cement is the most important material which plays a very important role in attaining the strength of concrete. Cement is a very fine powder made from calcining of lime and clay which acts as a binder in the construction. However the wide use of cement produces pollution causing emission of carbon dioxide which results into green house effect. So, in the recent times, scientists are searching for the partial replacement of cement which helps in improving the compressive strength and durability of concrete. For this they introduce Nano technology in this era. They find various Nano materials like Nano silica, Nano alumina, Nano titanium dioxide etc. which can be used as a partial replacement of cement for the improvement of strength and durability of the concrete. Out of the various Nano-materials, Nano-silica is one of the most important materials which are the first Nano product used in place of micro-silica. Nano-Silica when added with cement, react with free lime and forms C-S-H gel making the paste thicker and accelerate the process of hydration which ultimately results into the improvement of its compressive strength. A very small amount of Nano-silica is used to get the desired strength.

2. LITERATURE REVIEW

H. Li et. al. (2004) experimentally explored the mechanical property of nano-Fe_2O_3 and nano-SiO_2 cement mortars and observed that the 7- and 28-day strength were much greater than that for plain concrete. The microstructure examination illustrates that the nanoparticles enters into the pores and due to the occurrence of pozzolanic reaction, it reduces the amount of Calcium hydroxide

H. Li et.al. (2006) performed an experiment to find out the change in behaviour of concrete when it is amalgamated with the Nano particles of silica and titanium dioxide along with some particles of polypropylene fiber. It was find out that abrasion resistance of concrete can be improved effectively by blending the concrete with Nano particles and polypropylene fibers... It was observed that the effect of Nano titanium dioxide in improving the abrasion resistance of concrete is much higher than the effect of Nano silicon dioxide particles.

M.Nill et. al. (2009) investigated the effect of micro silica particles and colloidal Nano silica particles as a combination on concrete properties and observed that maximum compressive strength of the concrete is achieved when it has 6% micro-silica & 1.5% Nano-silica. The concrete has highest electrical resistivity when it contains 7.5% micro-silica and Nano-silica. When the concrete contains the combination of 1.5% Nano silica and 3% micro silica, it has lowest capillary absorption rate. .

Alirza Naji Giv et. al. (2010) analysed the size effect of Nano silica particles. The cement was replaced with Nano silica particles of two different sizes 15 nm and 80 nm with

0.5,1, 1.5 and 2%. b.w.c. He observed that the compressive strength of the concrete was increased in which maximum compressive strength was attained when the concrete was blended with 1.5% b.w.c. The various particle size of Nano silica particles are compared in which he found out that the maximum strength for 80 nm particles was more than that for 15 nm particles. He also observed that there was also an increment in flexural tensile strength and split tensile strength of concrete blended with Nano silica particles.

A. Sadrmotazi et. al. (2010), have analysed the combined effect of PP fiber along with Nano SiO2 particles. The cement mortar was mixed with 7% Nano silica which resulted in improvement of the Compressive strength of mortar by 6.49%. When PP fiber amount was increased beyond 0.3%, it results in reducing the compressive strength of mortar but an increment of its flexural strength, which shows the usefulness of Nano Silica particles...

Swami and Saikiran et.al. (2013) performed the experiment by mixing the M60grade and M70 grade concrete with combination of micro-silica and Nano-silica and found the result that concrete formed with the combination of these materials are more superior than the plain concrete.

Tavakoli et.al. (2013) combines both the Nano-silica and the micro-silica i.e., silica fume. He replaced the cement with silica fume of amount 5% and 10% and Nano-silica of amounts 0.5% and 1% and totally 8 mixtures were prepared for doing the various experiments of water absorption and compressive strength. By performing various experiments he attained the result that replacing cement with combined 10% silica fume and 1% Nano-silica increases the compressive strength by 42.2%.

Hasan Biricika et.al. (2014)compared the use of various materials such as fly ash, silica fume and nano-silica each of amounts 5% and 10% by weight. By conducting the tests, he found the result that 10% of each material silica fume, fly ash and Nano-silica respectively produces 18%, 44% and 84% compressive strength when compared to the controlled concrete.

Dr. D. V. Prasad Rao et.al. (2016) introduced the combined use of Metakaolin and Nano-silica with cement for the preparation of concrete. Initially, he replaced the cement with 5% and 10% metakaoline by weight. Further he replaced the cement with the combined weight of metakaoline (5% and 10%) and Nano-Silica (1%, 2% and 3%). Then the result of various properties of M25 grade concrete was noted down. From various results attained in the test, it has been seen that the concrete prepared with the above sample shows more strength as compared to the controlled concrete.

Summary

The various literature reviews show the importance of Nano-technology in construction era. The various properties of the concrete have been found to be improved.

3. MATERIALS AND METHODS

The materials used in this project are:

- 43 grade OPC
- Nano silica
- Coarse aggregate
- Fine aggregate
- Water

Properties of Cement:

Specific Gravity-3.14
Fineness by sieve analysis- 2.01%
Normal Consistency- 33%

Properties of fine and coarse aggregate:

Property	Coarse Aggregate	Fine Aggregate
Specific Gravity	2.74	2.65
Bulk Density	1.44	1.408
Void Ratio	1.0085	0.58

Properties of Nano SiO2:

Test Item	Standard Requirement	Test Results
pH value	3.7-4.5	4.15
Specific surface area(m^2/g)	200±20	205
Sieve Residue	≤0.04	0.03
SiO_2content (%)	≥99.8	99.9
Al_2O_3	≤0.03	0.005
TiO_2	≤0.02	0.004
Fe_2O_3	≤0.03	0.001

EXPERIMENTAL PROGRAMME

Specimens of M30 grade concrete were prepared and their compressive strength was compared with different replacement levels of cement with Nanosilica (0.5%, 1%, 2% and 3%).

Mix Proportions of concrete:

A. Cement = 390 Kg/m^3
B. Water = 175 Kg/m^3
C. Fine Aggregate = 864.33 Kg/m^3
D. Coarse Aggregate = 1021.71 Kg/m^3
E. Water cement ratio= 0.45

4. RESULTS AND DISCUSSIONS:

4.1. UPV Test Result

7-Day Test Results:

Table 4.1.1: UPV Test for control specimenfor 7 days

Sample No.	Weight (kg)	Velocity (m/s)	Time (µs)
1	8.41	4700	31.91
2	8.54	4740	31.64
3	8.53	4775	31.49

Table 4.1.2: UPV Test for specimen with Nano silica 0.5%b.w.c for 7 days

Sample No.	Weight (kg)	Velocity (m/s)	Time (µs)
1	8.10	4520	33.33
2	7.95	4495	33.37
3	8.30	4390	34.20

Table 4.1.3: UPV Test for specimen with Nano-silica 1% b.w.c for 7 days

Sample No.	Weight (kg)	Velocity (m/s)	Time (µs)
1	8.26	4590	32.68
2	8.11	4600	32.61
3	7.02	4690	31.98

Table 4.1.4: UPV Test for specimen with Nano-silica 2% b.w.c for 7 days

Sample No.	Weight (kg)	Velocity (m/s)	Time (µs)
1	8.40	4400	32.68
2	8.24	4430	32.61
3	8.31	4450	31.98

Table 4.1.5: UPV Test for specimen with Nano-silica 3% b.w.c for 7 days

Sample No.	Weight (kg)	Velocity (m/s)	Time (µs)
1	8.26	4495	33.37
2	8.30	4390	34.16
3	8.10	4385	34.20

28 Day Test Results:

Table 4.1.6: UPV Test for control specimen for 28 days

Sample No.	Weight (kg)	Velocity (m/s)	Time (µs)
1	8.30	4795	31.28
2	8.20	4900	30.61
3	8.00	4805	31.22

Table 4.1.7: UPV Test for specimen with Nano-silica 0.5% b.w.c for 28 days

Sample No.	Weight (kg)	Velocity (m/s)	Time (µs)
1	8.15	4700	31.90
2	8.00	4750	31.59
3	7.90	4790	31.32

Table 4.1.8: UPV Test for specimen with Nano-silica 1% b.w.c for 28 days

Sample No.	Weight (kg)	Velocity (m/s)	Time (µs)
1	7.95	4690	31.98
2	8.20	4610	32.53
3	8.10	4650	32.26

Table 4.1.9: UPV Test for specimen with Nano-silica 2% b.w.c for 28 day

Sample No.	Weight (kg)	Velocity (m/s)	Time (µs)
1	8.40	4650	32.26
2	8.90	4690	31.98
3	8.20	4700	31.91

Table 4.1.10: UPV Test for specimen with Nano-silica 3% b.w.c for 28 day

Sample No.	Weight (kg)	Velocity (m/s)	Time (µs)
1	8.10	4590	32.67
2	8.15	4570	32.82
3	8.00	4600	32.60

Comparison of UPV Test Results

From the UPV test results, we find that the quality of concrete is very good. The 28-day quality is better than the 7-day quality. The blended concrete specimen is found to have better quality compared to the control specimen.

4.2. Compressive Strength Test Result

Comparison of Compressive Strength Test Result:

Table 4.2.1: Comparison of compressive strength for 7 day

Specimens	Strength (MPa)	Increase in strength (%)
Control	21.58	-
NS 0.5%b.w.c	22.58	1.57
NS 1%b.w.c	25.02	10.80
NS 2%b.w.c	26.90	7.51
NS 3%b.w.c	25.96	-3.49

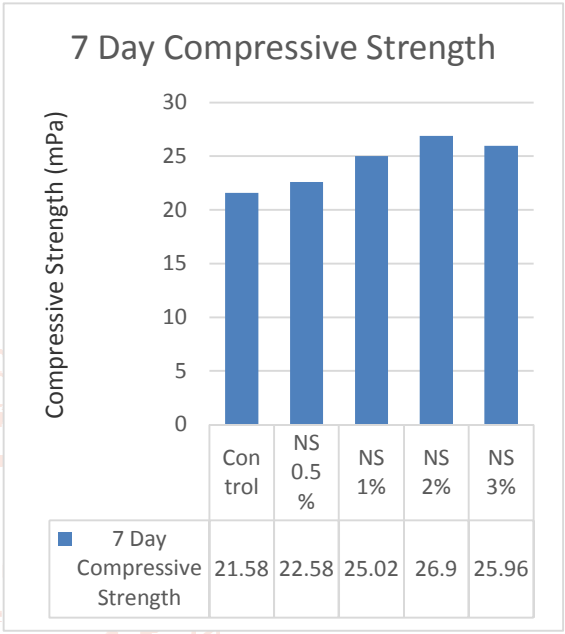

Fig. 4.1: 7-day compressive strength of four specimens

Table 4.2.2: Comparison of compressive strength for 28 day

Specimens	Strength (MPa)	Increase in strength (%)
Control	32.86	-
NS 0.5%b.w.c	33.67	2.46
NS 1%b.w.c	36.23	7.6
NS 2%b.w.c	38.83	7.17
NS 3%b.w.c	37.57	-3.2

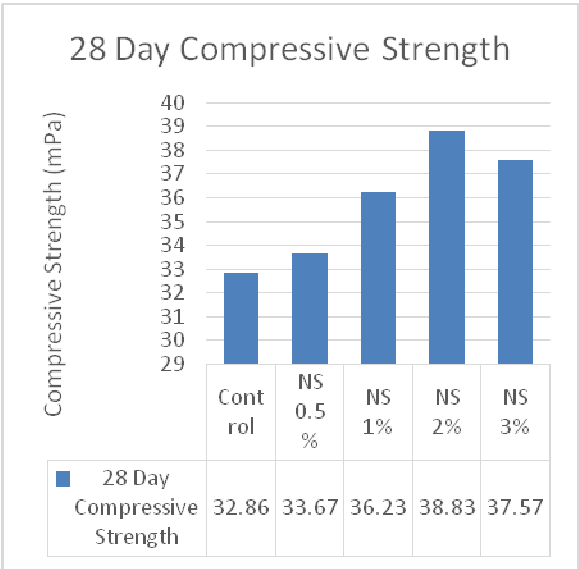

Fig. 4.2: 28-day compressive strength of four specimens

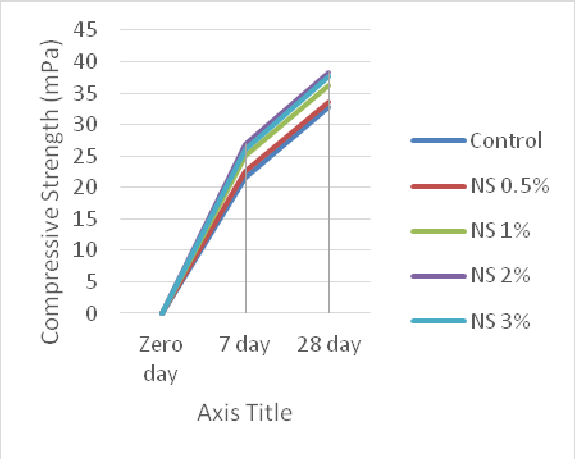

Fig. 4.3: Change in compressive strength of four specimen from 7 day to 28 day

Table 4.2.3: Flexural strength of concrete for 28 day

Flexural Strength of Concrete (28 days)		
Concrete Mix	**Experimental Flexural Strength (MPa)**	**Theoretical Flexural Strength (MPa)=0.7**
Without Silica	4.08	4.012
0.5 % Nano Silica	4.091	4.061
1 % Nano Silica	4.34	4.21
2 % Nano Silica	4.45	4.36
3 % Nano Silica	4.37	4.29

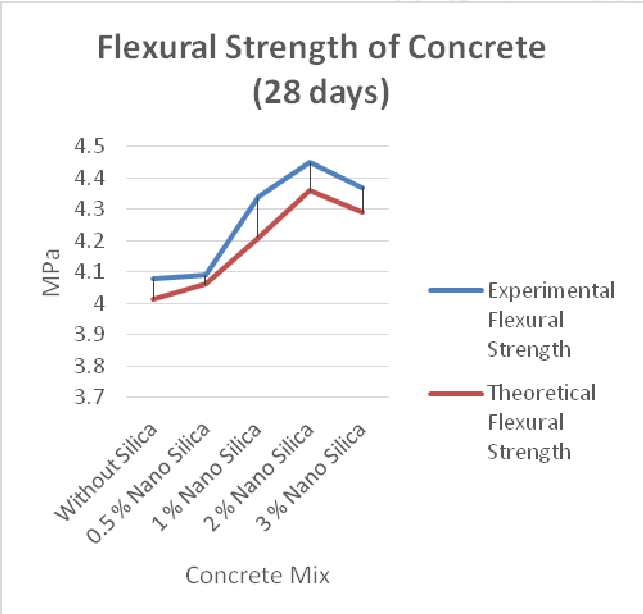

Fig. 4.4: 28-day flexural strength of four specimens

Table 4.2.4: Splitting tensile strength for 28 day

Splitting Tensile Strength	
Concrete Mix	**Splitting Tensile Strength**
Without Silica	2.80
0.5 % Nano Silica	2.90
1 % Nano Silica	2.99
2 % Nano Silica	3.10
3 % Nano Silica	3.05

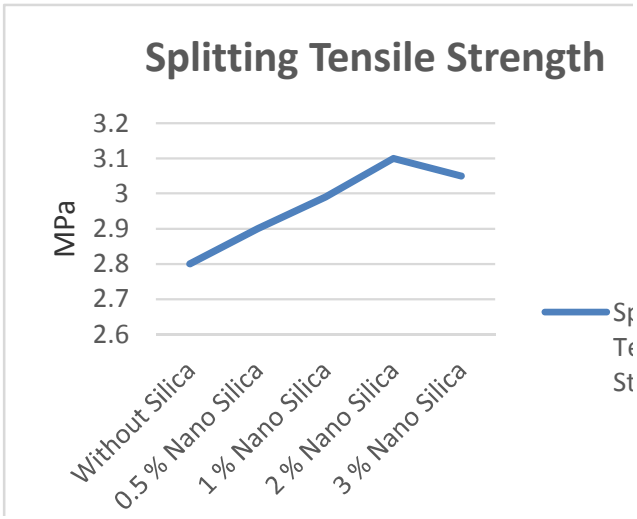

Fig. 4.5: splitting tensile strength of four specimen

5. CONCLUSION

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 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 Nano SiO2 there is a substantial increase in the early-age strength of concrete compared to the 28 day increase in strength.
3. The UPV test results show that the quality of concrete gets slightly affected on addition of Nano SiO2 but the overall quality of concrete is preserved.
4. The results of splitting tensile strength experimental study for different concrete mixes at 28-day and specimens under different confinement. It is clear that the relationship between splitting tensile strength and compressive strength was similar for both VC and SCC. Therefore, the same model can be applied to both concrete types.
5. The results of flexural tensile strength experimental study are given for different concrete mixes at 28-day and specimens under different confinement. It is clear that the flexural tensile strength increases when the compressive strength and age of the concrete increase. Moreover, the increase in the flexural strength is lower than the corresponding increase in the compressive strength at same age ofconcrete. The percentage increase in flexural tensile strength decreases with the increase of level of concrete strength.

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