ISSN: 0474-9030
Vol-68-Issue-1
January-2020

EXPERIMENTAL STUDIES ON COMPRESSION AND FLEXURE TEST ON NANO BASED CARBON FIBER WITH REINFORCED CONCRETE

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Abstract: The application of nanotechnology in concrete has added a new dimension to the efforts to improve its properties. Nano-materials, by virtue of their very small particle size can affect the concrete properties by altering the microstructure. This study concerns with the use of nanosilica of size 236 nm to improve the compressive strength of concrete. An experimental investigation has been carried out by replacing the cement with nanosilica of 0.3%, 0.6% and 1% b.w.c. The tests conducted on it show a considerable increase in early-age compressive strength and a small increase in the overall compressive strength of concrete. The strength increase was observed with the increase in the percentage of nanosilica. The FESEM micrographs support the results and show that the microstructure of the hardened concrete is improved on addition of nanosilica.

Keywords Nano-materials, microstructure, compressive strength.

1. INTRODUCTION

Nano-materials are very small sized materials with particle size in nano meters. These materials are very effective in changing the properties of concrete at the ultrafine level by the virtue of their very small size. The small size of the particles also means a greater surface area (Alireza Naji Givi, 2010). Since the rate of a pozzolanic reaction is proportional to the surface area available, a faster reaction can be achieved. Only a small percentage of cement can be replaced to achieve the desired results. These nanomaterials improve the strength and permeability of concrete by filling up the minute voids and pores in the microstructure.

The use of nanosilica in concrete mix has shown the increase in the compressive, tensile and flexural strength of concrete. It sets early and hence generally requires admixtures during mix design. Nanosilica mixed cement can generate nanocrystals of C-S-H gel after hydration. These nanocrystals accommodate in the micro pores of the cement concrete, hence improving the permeability and strength of concrete.

The increased use of cement is essential in attaining a higher compressive strength. But, cement is a major source of pollution. The use of nanomaterials by replacement of a proportion of cement can lead to a rise in the compressive strength of the concrete as well as a

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check to pollution. Since the use of a very small proportion of Nano SiO2 can affect the properties of concrete largely, a proper study of its microstructure is essential in understanding the reactions and the effect of the nanoparticles. Existing research works shown the use of admixtures in concrete mix. In the present study, no admixture has been used in order to prevent the effect of any foreign material on the strength of the concrete. This study is an attempt to explain the impact of a nanosilica on the compressive strength of concrete by explaining its microstructure.

2. OBJECTIVE OF THE STUDY

The main objectives of the present study are as mentioned below:

- To study the effect of nanosilica on the compressive strength of concrete.
- To study the microstructure of the hardened cement concrete.
- To explain the change in properties of concrete, if any, by explaining the microstructure.

2.1 Scope of Work

The present study incorporates mix design based on the guidelines as per Indian Standard code IS 10262-2009. The nanosilica used is imported from a supplier. The use of any kind of admixture is strictly prohibited in the mix design. The water content has been kept constant to facilitate a better comparison for different samples. The compressive strength measurements are carried out for 7-day and 28-day and the FESEM analysis has been done for 28-day only. The size of the nanosilica was identified using Particle Size Analyzer.

3. MATERIALS AND METHODS

This section describes about 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.

3.1 Material Properties

The materials used to design the mix for M25 grade of concrete are cement, sand, coarse aggregate, water and Nano SiO2. The properties of these materials are presented below:

Properties of Nano SiO2

The average size of nanosilica was found to be 236 nm from Particle Size Analyzer.

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The properties of the material are shown in Table 3.3. Fig. 3. Shows the nanosilica used in the experiment.

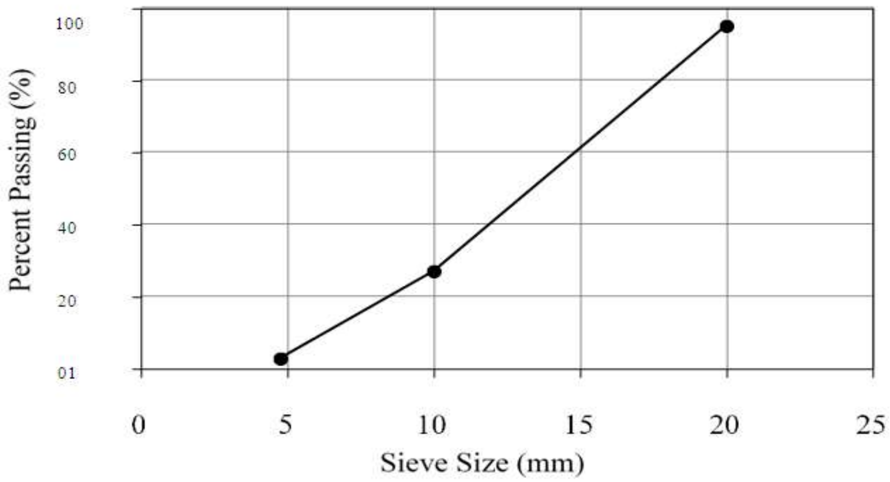

Fig. 1: Size distribution curve for coarse aggregate

Fig. 2 Image of the Nano SiO2 used

Table 1 Properties of Nano SiO2

TEST ITEM	STANDARD REQUIREMENTS	TEST RESULTS
Specific surface area (m^2/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

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Chloride content (%)	≤ 0. 0202	0. 009
Al2O3	≤ 0. 03	0. 005
TiO2	≤ 0. 02	0. 004
Fe2O3	≤ 0. 003	0. 001

4. EXPERIMENTAL VERIFICATION AND MICROSTRUCTUREANALYSIS

This section presents the results of the experiments carried out towards the objective of the research. It includes results from compressive strength test, UPV Test and FESEM. The results are supplemented with graphs in order to have a better analysis of the results.

4.1 EXPERIMENTAL RESULTS

4.1.1 Comparison of Compressive Strength Results

The change in compressive strength for the blended sample (in %) for 7 and 28 day is shown in Table 2 and Table 3 respectively. A graphical representation of this result is shown in Figure 3 and Figure 4. The change in compressive strength from 7 day to 28 day is shown in Figure 5.

Table 2. Comparison of compressive strength for 7 day

7-DAY RESULTS	STRENGTH (MPa)	INCREASE IN STRENGTH (%)
CONTROL	26.30	-
NS 0.3% b.w.c	27.61	4.98
NS 0.6% b.w.c	31.10	18.25
NS 1% b.w.c	34.59	31.52

NS= Nano SiO_2

Table 3. Comparison of compressive strength for 28 day

28-DAY RESULTS	STRENGTH (MPa)	INCREASE IN STRENGTH (%)
CONTROL	35.31	-
NS 0.3% b.w.c	35.17	-0.39
NS 0.6% b.w.c	36.48	3.31
NS 1% b.w.c	39.82	12.77

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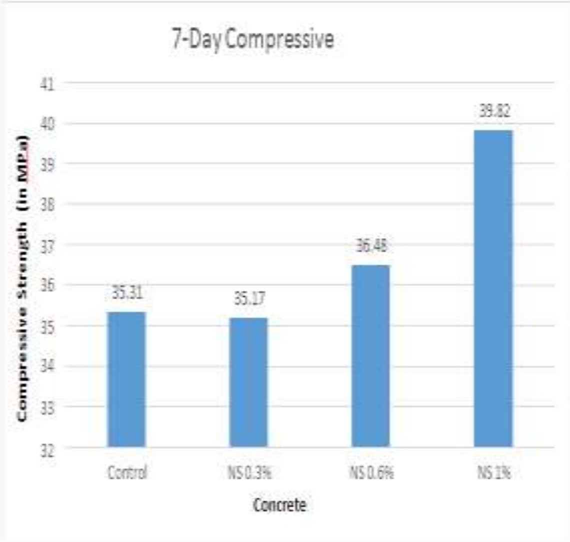

Figure 3. 7-day compressive strength of four specimens

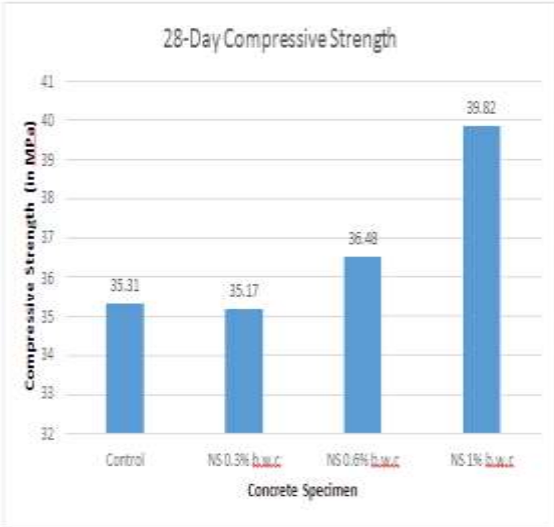

Figure 4. 28-day compressive strength of four specimens

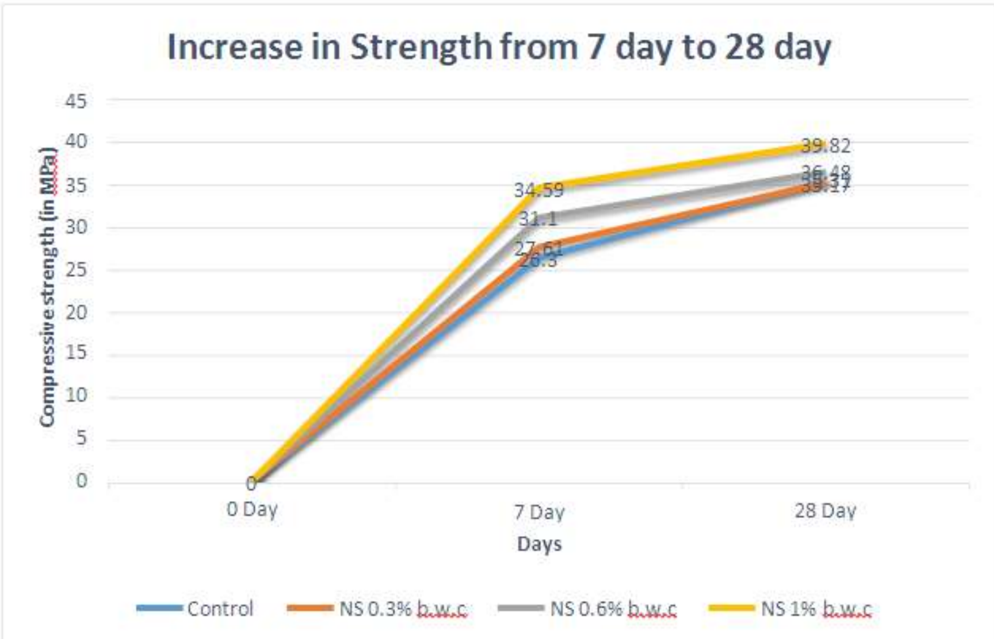

Figure 5. Change in compressive strength from 7 day to 28 day

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

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blended with nanosilica but later the increase in strength is subdued.

4.1.2 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 control specimens are found to have better quality compared to the blended concrete specimen.

4.1.3 Field Emission Scanning Electron Microscope (FESEM) IMAGES

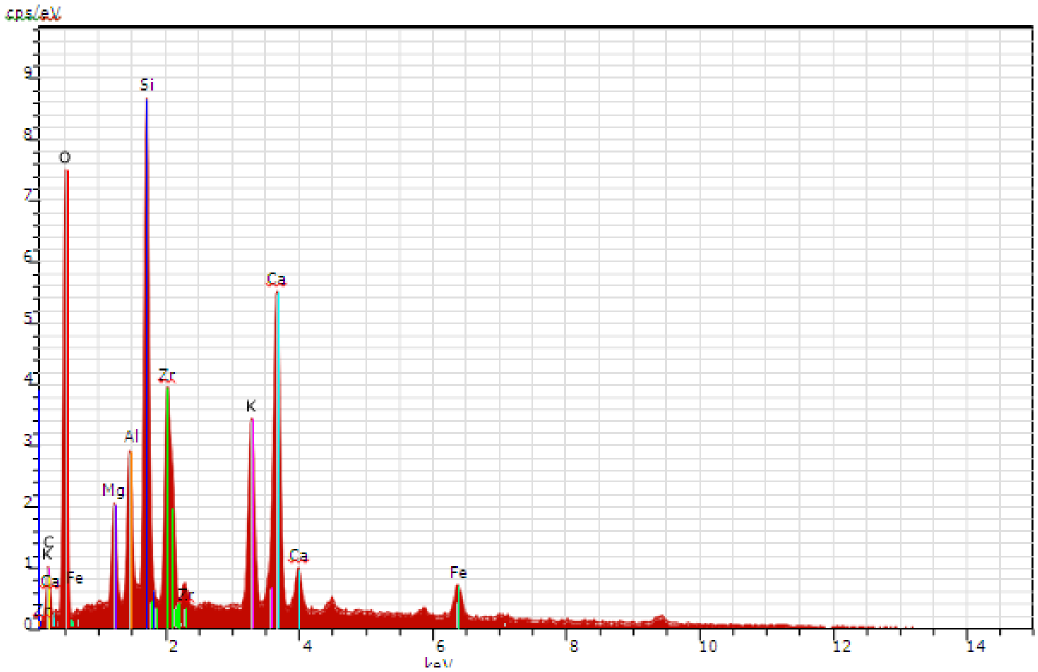

Figure 6. Relative chemical composition for the control specimen

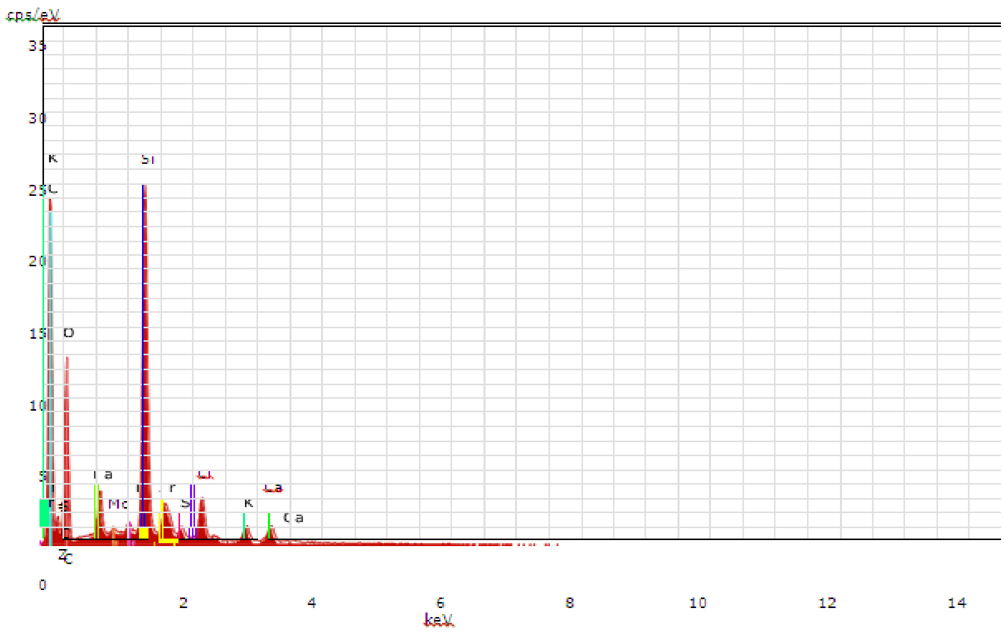

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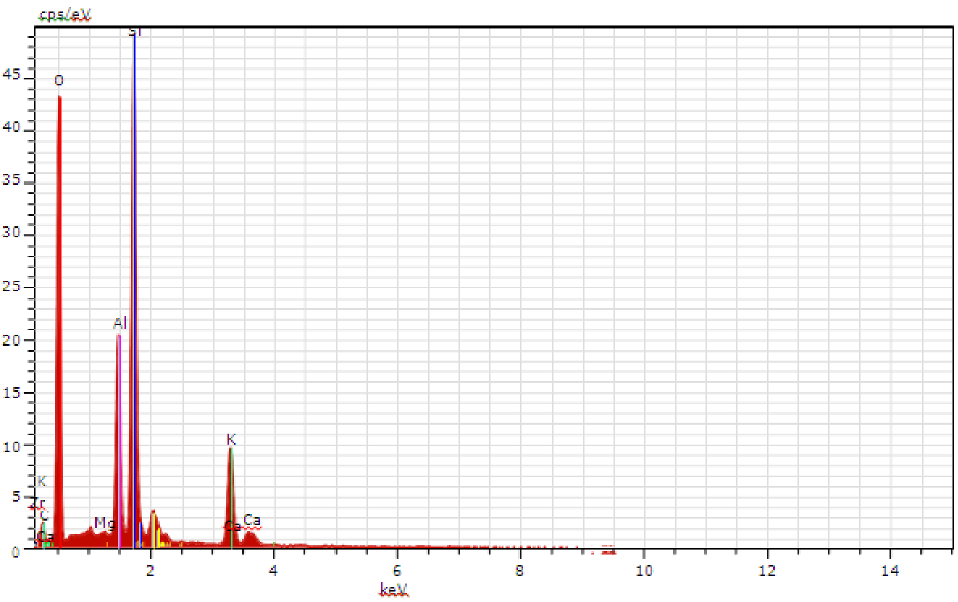
Figure 7. Relative chemical



composition for specimen with NS 0.3% b.w.c

Figure 8. Relative chemical composition for specimen with NS 0.6% b.w.c

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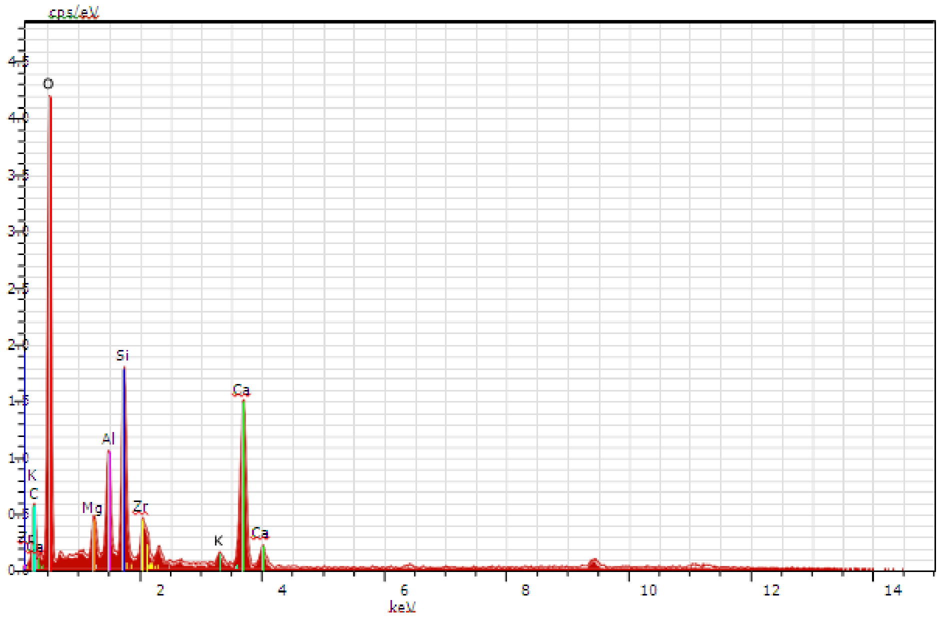

Figure 9. Relative chemical composition for specimen with NS 1% b.w.c

4.1.4 Comparison of FESEM micrographs

Figure 6 shows the FESEM micrograph of concrete specimen without nanosilica (NS). In this figure it can be clearly seen that the C-S-H gel is scattered with lots of empty spaces in between the lumps. The lumps can be Ca(OH)2 which weakens the Interfacial Transition Zone (ITZ) hence affecting the strength. The microstructure looks to contain mainly amorphous substances.

Figure 7 shows the FESEM micrograph of concrete specimen with NS 0.3% b.w.c. Here 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 NS particles occupying the pores in C-S-H gel gives the compact structure but are not sufficient in amount to react with Ca(OH)2 and produce C-S-H gel. Figure 8 shows the FESEM micrograph of concrete specimen with NS 0.6% b.w.c. A uniform microstructure with very little void can be seen. The absence of Ca(OH)2 crystals indicates that NS has reacted with Ca(OH)2 and converted it into C-S-H gel. Figure 9 shows the FESEM micrograph of concrete specimen with NS 1% b.w.c. The microstructure is very dense and many crystalline lumps can be observed. These lumps indicate the agglomeration of Nano SiO2 particles which make the structure crystalline and hence enhance the strength.

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4.1.5 Comparison of Chemical Composition of the Specimen

Figure 6 shows the relative chemical composition of concrete specimen without nanosilica (NS). High concentration of calcium is due to the formation of $Ca(OH)_2$ crystals which weakens the ITZ. Figure 7 shows the relative chemical composition of concrete specimen with NS 0.3% b.w.c. A high concentration silicon and low concentration of calcium and oxygen shows that silica has got into the structure but hasn't reacted with the $Ca(OH)_2$ to produce C-S-H gel of which calcium occupies a good portion. These silica particles occupy the pores in the gel and make the microstructure uniform. Figure 8 shows the relative chemical composition of concrete specimen with NS 0.6% b.w.c. This figure looks contradicting due to high percentage of silica and low percentage of calcium. A good percentage of oxides can be due to the reaction of silica with $Ca(OH)_2$ which produces C-S-H gel. Another explanation to the increase in strength can be due to the availability of sufficient silica to make the microstructure denser and uniform. Figure 9 shows the relative chemical composition of concrete specimen with NS 1% b.w.c. The high percentage of oxygen and comparable amount of Ca and Si shows a good reaction between silica and $Ca(OH)_2$ to produce C-S-H gel and hence an increase in strength is observed.

5 CONCLUSION

From the test results, the SEM micrographs and the relative chemical composition of the specimen a number of conclusions can be drawn. These conclusions are justified in the next section. The conclusions drawn are:

i. 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 SiO_2. The increase in strength is maximum for NS 1% b.w.c and least for NS 0.3% b.w.c.

ii. On addition of Nano SiO_2 there is a substantial increase in the early-age strength of concrete compared to the 28 day increase in strength.

iii. The UPV test results show that the quality of concrete gets slightly affected on addition of Nano SiO_2 but the overall quality of concrete is preserved.

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iv. The FESEM micrograph shows a uniform and compact microstructure on addition of Nano-SiO_2.

5.1 Scope for Future Research

Although a lot of work has been carried out involving the use of nano silica in concrete, a proper understanding has not been developed. In future, the size effects of nano silica can be studied in detail. A detailed study of the microstructure at specific intervals throughout a year can give a very good idea about the reactions taking place in the concrete. Looking at the price of the nano silica new methods can be designed for its production at a low cost.

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