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Effect on Compressive Strength of Concrete by use of Nano Silica as Partial Replacement of Cement

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Abstract — *Concrete composite is one of the main construction materials in civil engineering, with large quantities of it being consumed all over the world each year. Cement is an important raw material in the production of concrete composite. During manufacturing of cement, large amounts of carbon dioxide (CO_2) get into the atmosphere. So, it is required to use a Green concrete that will result in the sustainable development without destruction of natural resources. The major objective behind green concrete is to reduce CO_2 emission from cement industry. The application of nanotechnology in concrete has added a new dimension to the efforts to improve its properties. Nanomaterials, by virtue of their very small particle size can affect the concrete properties by altering the microstructure. This study concerns with the use of nano silica to improve the compressive and tensile strength of concrete. An experimental investigation has been carried out by replacing the cement with nano silica of 2.0%, 3.0% and 4.0% by weight of cement. The tests conducted on it shows a considerable increase in compressive and tensile strength of concrete. The strength increase was observed with the increase in the percentage of nano silica.*

Keywords- *Nano Silica, Cement, Concrete, Compressive Strength, Tensile Strength.*

I. INTRODUCTION

Concrete is the material of present as well as future. The wide use of it in structures, from buildings to factories, from bridges to airports, makes it one of the most investigated material of the 21st century. Due to the rapid population explosion and the technology boom to cater to these needs, there is an urgent need to improve the strength and durability of concrete. Out of the various materials used in the production of concrete, cement plays a major role due its size and adhesive property. So, to produce concrete with improved properties, the mechanism of cement hydration must be studied properly and better substitutes to it have to be suggested. Different materials known as supplementary cementitious materials or SCMs are added to concrete improve its properties. Some of these are fly ash, blast furnace slag, rice husk, silica fumes and even bacteria. Of the various technologies in use, nano-technology looks to be a promising approach in improving the properties of concrete.

Nanomaterials are very small sized materials with particle size in nanometres. 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. 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 increased use of cement is essential in attaining a higher compressive strength. 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 check to pollution. Since the use of a very small proportion of Nano SiO_2 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. The existing papers show the use of admixtures in concrete mix This study is an attempt to explain the impact of a nano-silica on the compressive strength of concrete by explaining its microstructure.

The use of nano silica in concrete mix has shown results of increase in the compressive, tensile and flexural strength of concrete. It sets early and hence generally requires admixtures during mix design. Nano-silica mixed cement can generate nano-crystals of C-S-H gel after hydration. Nano silica having a low-cost budget compared to other nano materials. It helps to gain Concrete high compressive, tensile and flexural strength compared to normal Concrete. It has high surface area, reducing percentage of CO_2, as nano silica is added in concrete to fill in the voids, decrease the concrete alkalinity, and increases its resistance against the chemical attack.

II. MATERIALS USED

The materials used for the preparation of concrete are as follows: -

A. ***Cement:*** The cement used in this study was Ordinary Portland cement of 53 grade (Sanghi Cement) conforming to IS12269-1987.

Table 1: Properties of Cement

Properties	Value
Specific Gravity of Cement	3.15
Initial Setting Time	32 minutes
Final Setting Time	290 minutes
Standard Consistency	31%

B. ***Fine Aggregate:*** Locally available clean and dry sand was used. The sand was conforming to Zone II as per IS: 383-1987. The properties of fine aggregate are shown in table 2.

Table 2: Properties of Fine Aggregate

Properties	Value
Specific Gravity	2.60
Bulk density, kg/m^3	1650
Fineness Modulus	2.251
Water Absorption	0.6%

C. ***Coarse Aggregate:*** Coarse aggregate are used for making concrete. They may be in the form of irregular broken stone or naturally occurring gravel. Material which are large to be retained on 4.75mm sieve size are called coarse aggregates. Its maximum size up to 40 mm.

Table 3: Properties of Coarse Aggregate

Properties	Value
Specific Gravity	2.90
Bulk density, kg/m^3	1800
Fineness Modulus	6.00
Water Absorption	0.20%

D. ***Water:*** Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Since it helps to from the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. Portable water is generally considered satisfactory.

E. ***Nano Silica:*** Nano Silica of particle size about 200 nm is used as partial replacement of 2%, 3% and 4% by weight of cement.

Table 4: Properties of Nano Silica

Properties	Value
Specific Surface Area (m^2/g)	202
PH Value	4. 12
Loss on Drying @ 105 ^oC (5)	0. 47
Loss on Ignition @ 1000 ^oC (%)	0.66
Sieve Residue (5)	0. 02
Tamped Density (g/L)	44
SiO_2 Content (%)	99. 88
Carbon Content (%)	0. 06
Chloride Content (%)	0. 009
Al_2O_3	0. 005
TiO_2	0. 004
Fe_2O_3	0. 001

III. EXPERIMENTAL PROCEDURE

The aim of the Experiment was to assess the properties of Concrete made with Nano Silica and to study the important aspect that is compressive and Tensile strength. The studies were carried out for M30 mix design of concrete. Concrete include cement, water, fine aggregate, coarse aggregate. The specimen used for the Compressive and Tensile strength tests were Cubes and Cylinders. The Nano Silica is used as partial replacement of Cement in the range of 2%, 3%, 4% as per its weight and its optimum level is to be found. For analysing the Nano Silica and other variation mix totally 36 cubes of size 150x150x150mm were casted for compression strength test and 36 Cylinders of 150mm diameter and 300mm length were casted for tensile strength test. Once 24hours completed from casting the concrete specimens are opened and allowed for continuous curing in a tank with portable water. The specimens are taken and tested at required 7th day and results were carried out, while the 14 day and 28 day tests are being carried out. The quantities of material for M30 grade is given in Table 5.

Table 5: Quantities of Material (M30 grade)

Percentage Nano Silica	Weight of Cement (kg/m^3)	Weight of Nano Silica (kg/m^3)	Weight of Water (kg/m^3)	Weight of Coarse Aggregate (kg/m^3)	Weight of Fine Aggregate (kg/m^3)
0%	456.00	0	191	1068	603
2%	446.88	9.12	191	1068	603
3%	442.32	13.68	191	1068	603
4%	437.76	18.24	191	1068	603

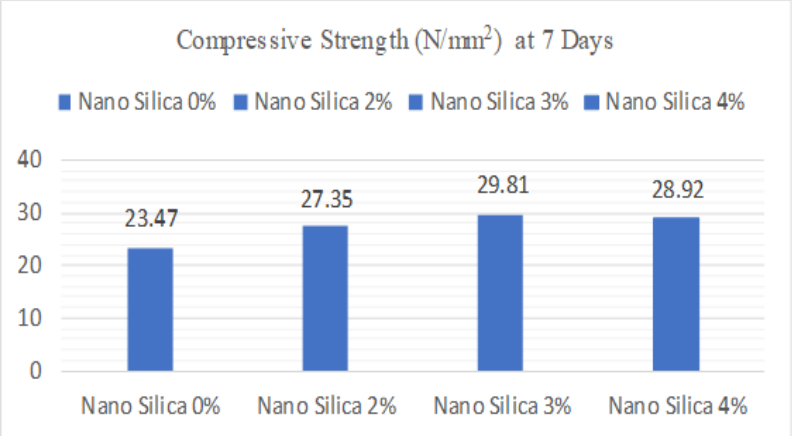
IV. RESULTS AND DISCUSSION

A. Compressive Strength Test

The compressive strength of M30 grade concrete at the age of 7 days is shown in Table 6. There is a significance improvement in the strength of concrete because of high pozzolanic nature of nano silica and their filling ability. Compressive strength of mix at 7 days age, with replacement of Nano Silica was increased gradually up to an optimum replacement level of 3% and then decreased. The maximum 7 days cube strength of M30 grade with 3% of Nano Silica was 29.81 N/mm^2.

Table 6: Results of Compressive Strength Test at 7 Days

Percentage Nano Silica	Compressive Strength at 7 days (N/mm^2)	Percentage increase
0%	23.47	0
2%	27.35	16.53
3%	29.81	27.01
4%	28.92	23.22

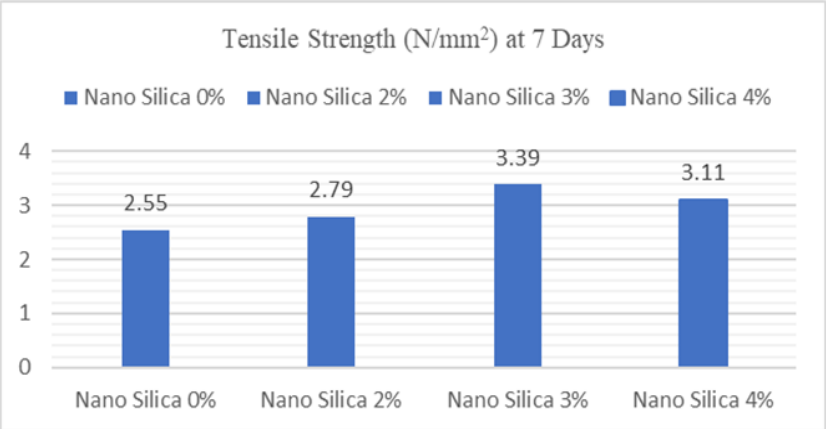


B. Tensile Strength Test

The Tensile strength of M30 grade concrete at the age of 7 days is shown in Table 7. Tensile strength of mix at 7 days age, with replacement of Nano Silica was increased up to replacement level of 3% and then decreased. The maximum 7 days Tensile strength of M30 grade with 3% of Nano Silica was 3.39 N/mm^2

Table 7: Results of Tensile Strength Test at 7 Days

Percentage Nano Silica	Tensile Strength at 7 days (N/mm^2)	Percentage increase
0%	2.55	0
2%	2.79	9.41
3%	3.39	32.94
4%	3.11	21.96



V. CONCLUSION

The compressive strength of concrete initially increased up to 3% of Nano-Silica and with further increase in the Nano Silica content the compressive strength of concrete decreases. Concrete containing lower percentages (3%) of Nano Silica possess higher values of compressive strength than that of Normal concrete. A considerable increase in tensile strength of Nano-Silica containing concrete was observed compared to normal concrete. Based on the experimental results, use of Nano-Silica as partial replacement of cement in small quantities is advantageous on the performance of concrete. Nano-Silica added in small quantities can improve the compressive and tensile strength of concrete.

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