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Strength Evaluation and Durability on Addition of Nanosilica in M30 Grade Concrete

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Abstract: Nano technology plays a very vital role in all the areas of research. The incorporation of nano materials in concrete offers many advantages and improves the workability, the strength and durability properties of concrete. In this study an attempt has been made to carry out an experimental investigation on concrete in which cement was replaced with nano sized cement. Nano-silica has a unique advantage in the potential pozzolanic-reaction with cement hydration products over other nanoparticles. Addition of Nano-silica is known to redefine pore size and distribution which would alter the durability of the concrete. Ordinary Portland cement of 53 grade was ground in a ball grinding mill to produce nano cement. . Nano technology is an emerging field of interest for civil engineering utility. A few of the nano substances presently used in concrete, nano-silica very own greater pozzolanic nature. It has the functionality to react with the unfastened lime inside the route of the cement hydration and bureaucracy extra C-S-H gel giving strength, impermeability and durability to concrete. Present paper investigates the effects of addition of nano silica in normal strength of concrete.

The present research deals with Partial alternative cement through nano silica powder as partial replacements in concrete at associate with various materials like OPC53 grade cement, fine aggregate, coarse aggregate to check their suitability for making concrete. The mix proportions of concrete were modified as micro silica (5%, 7.5%, 10%, 15%) and nano silica (1%, 1.5%, 2%, 2.5%) as partial replacement of cement. The cubes were cast by replacing Specimens were cast as per mix design and the tests are conducted after proper curing, the tests are compressive strength of cubes (150mm x 150mm x 150mm) and split tensile strength of cylinders (150mm x 300mm). The results had been compared with the outcomes of concrete specimens with 0% of nano silica.

Keywords: M30 grade, nano silica, Nano technology,pozzolanic-reaction

I. INTRODUCTION

A. General

Concrete is one of the prime materials for structures and it is widely used for various applications all over the world. Aggregates and cement play a major role in concrete. In India there is a great shortage of natural aggregates. Production of cement liberates same amount of carbon dioxide which is the great cause of ozone depletion. This effect creates a question on the sustainability of concrete. In order to make concrete a sustainable material, suitable engineering approaches can be done.

Apart from this waste generation has increased considerably and find no way for disposal. In order to overcome this, industrial and agro- waste materials can be used as alternate building materials. In this present study I made an attempt by utilizing industrial waste such as silica fume (micro silica) and nanosilica as suitable substitutes in concrete.

B. Advantages Of Using Silica Fume

1) High early compressive strength
2) High tensile flexural strength and modulus of elasticity
3) Very low permeability to chloride and water intrusion
4) Enhanced durability
5) Increased toughness
6) Increased abrasion resistance on decks, floors, overlays and marine structures
7) Superior resistance to chemical attack from chlorides, acids, nitrates and sulfates and life-cycle cost efficiencies
8) Higher bond strength
9) High electrical resistivity and low permeability

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C. Advantages of Nano Silica

1) Nanosilica as a partial substitute of cement increases density and improves performance of concrete. Modulus of elasticity of nano- silica material concrete may reach about 2 times of the normal concrete modulus of elasticity.
2) The maximum compressive strength of nanosilica concrete at age of 28 days (10% nanosilica composition) reached 115 MPa
3) Concrete with nanosilica ingredient increases the strain and ductility of the concrete.
4) Nanosilica concrete is denser than concrete without nanosilica.

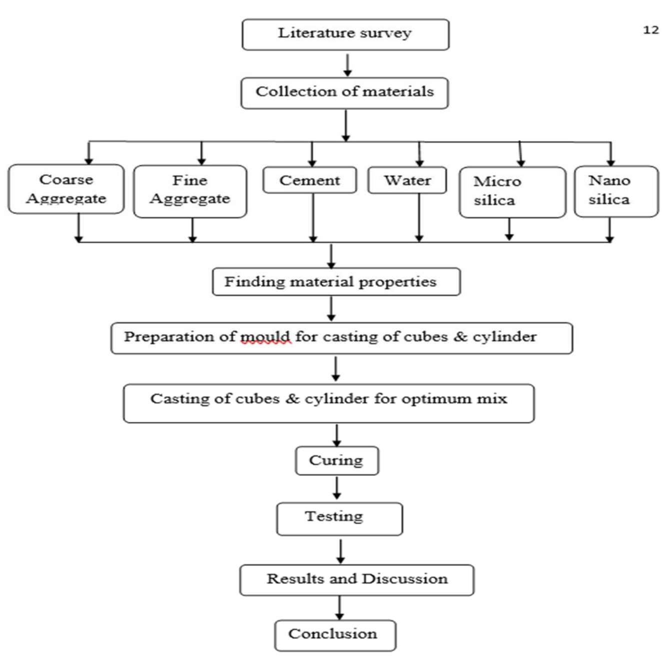
II. LITERATURE REVIEW

The usage of industrial by-products especially industrial by-products in making of concrete is an important study of worldwide interest. Many researchers have investigated the possible use of micro silica and nano silica as a partial replacement of cement. For this study, some of the important literatures were reviewed and presented briefly

A. Reviews on Literature

1) *Ping Duan, Chunjie Yan , Wei Zhou (2016)* has done a study on "Compressive strength and microstructure of fly ash based geopolymer blended with silica fume under thermal cycle". This paper states that silica fume plays an important role in the compressive strength even though it increases only by 6.7% when 10% silica fume is added compared to reference sample. It can be observed that geopolymer SF30 containing 30% silica fume coupled with 70% fly ash exhibits the highest compressive strength.
2) *A.Ranjani1, K.Keerthana2, N.K.Amudhavalli (2016)* reported a "Study on effect of micro silica and nano silica in polyester fibre reinforced concrete". This study is mainly concentrated on the mechanical characteristics of FRC with partial replacement of cement by micro silica (2%, 4%, 6%, 8 % and 10%) and nano silica (0.5%, 1.5%, 1%, 2 %, and 2.5%).
3) *Saber Fallah, Mahdi Nematzadeh (2016)* studied the "Mechanical properties and durability of high-strength concrete containing macro-polymeric and polypropylene fibers with nano-silica and silica fume" Nano-silica and silica fume with the weight percentages of 2and 12%, respectively, exhibit the strongest influence on the compressive strength of high-strength concrete with the associated improvements of 14.0 and 41.1%, respectively. Furthermore, using 3% nano-silica and 10% silica fume with an increase of 16.1 and 28.4%, respectively, demonstrates the highest improvement in the tensile strength.
4) *Satya Jit Parida (2015)* studied the compressive strength of concrete with silica fume at 7days and 28 days. The addition of silica fume was 0, 0.3, 0.6 & 1 % for M25 grade of concrete. The compressive strength was maximum at 1% addition of NS In both 7 & 28 days. For 7th day at 1% it was 34.59 MPa & at 28th day it was 39.82 MPa.

III.METHODOLOGY



Methodology flow chart

IV. PRELIMINARY TEST

The empty weight of specific gravity bottle was noted as W1. The specific gravity bottle was filled with kerosene and weight noted as W4. Some of the kerosene was taken out and filled with cement and the weight measured as W3.
Weight of bottle with cement as W2 .Table 5.1 shows the specific gravity of cement.

Table Specific Gravity of Cement

S.No	Description	Trial No.1	Trial No.2	Trial No.3
1	Weight of empty bottle (W1) gm	68	68	68
2	Weight of bottle + cement (W2) gm	178	170	180
3	Weight of bottle + kerosene + cement (W3) gm	240	230	248
4	Weight of bottle + kerosene (W4) Gm	168	168	168
5	Specific gravity of cement	2.89	2.9	3.5

Specific gravity of cement = (W2- W1)/[(W2- W1)-(W3-W4)]. Specific gravity of cement = 3.15

A. Fine Aggregate

1) *Sieve Analysis:* The sample was brought to an air-dry condition before weighing and sieving. This was achieved either by drying at room temperature or heating at a temperature of 10000C to 11000C. The air-dry sample 3 kg was taken and sieved successively on the appropriate sieves starting with the largest size sieve as stated in the Table 5.2. Sieving was carried out on a machine not less than 10 minutes required for each test. Table 5.2 shows the sieve analysis of fine aggregate.

Table Sieve Analysis of Fine Aggregate

S.No	IS Sieve	Weight Retained (g)	Percentage of weight Retained	Cumulative percentage of Weight Retained	Cumulative percentage of passing
1	4.75	40	4	4	96
2	2.36	34	3.4	7.4	92.6
3	1.18	203	20.3	27.7	72.3
4	0.8	366.5	36.65	64.35	35.65
5	0.6	247	24.7	89.05	10.95
6	0.3	87.5	8.75	97.8	2.2
7	0.18	16.5	1.65	99.45	0.55
8	Pan	5.5	0.55	100	0
Total cumulative % of weight retained					310.25

Fineness Modulus of Fine aggregate = Total percentage of cumulative/100 Fineness Modulus of Fine aggregate= 3.10
Fine aggregate conforming to zone II as per IS 383-1970.

2) *Specific gravity:* The pycnometer was dried thoroughly and weighed as W1. Fill two third part of pycnometer with sand and was weighed as W2. The pycnometer was filled with water up to the top without removing the sand. Then it was shaken well and stirred thoroughly with the glass rod to remove the entrapped air. After the air was removed, the pycnometer was completely filled with water up to the mark. Then outside of the pycnometer was dried with a clean cloth and is weighed as W3. The pycnometer was cleaned thoroughly. The pycnometer was completely filled with water up to top. Then outside of the pycnometer was dried with a clean cloth and was weighed as W4. Table 5.3 shows the specific gravity for fine aggregate

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Table Specific Gravity of Fine Aggregate

S. No.	Observations	Trial No 1	Trial No 2	Trial No 3
1	Wt of empty container W1(gm)	620	620	620
2	Wt of container+sampleW2(gm)	874	882	862
3	Wt of container+sample+waterW3(gm)	1592	1602	1610
4	Wt of container+waterW4 (gm)	1448	1448	1448
5	Specific Gravity	2.3	2.43	2.42

Specific Gravity of Fine Aggregate = (W2-W1)/[(W2-W1)-(W3-W4)] Specific Gravity of Fine Aggregate = 2.38

3) Water absorption

Take 1000 g of fine aggregate (W1). The sample was filled with water and kept for 24 hours. After 24 hours immersion, the sample was taken out and dried in air for getting the saturated surface dry condition (SSD). Then, it was weighed (W2). Table shows the observed reading of water absorption of Fine aggregate.

Table Water Absorption of Fine aggregate

S. No.	Observations	Trial No 1	Trial No 2	Trial No 3
1	Weight of sample taken W1(gm)	1000	1000	1000
2	Weight of sample in SSD state W2(gm)	1009.8	1009	1008.2
3	Water Absorption	0.98	0.9	0.82

Water absorption = {(W1-W2)/W1)} x 100
Water absorption = 0.9%

B. Coarse Aggregate

1) *Sieve Analysis*: The sieve analysis procedure was similar to that of Fine aggregate. In this test, 2kg of sample was taken. Table shows the observed reading of sieve analysis test on coarse aggregate.

Table Sieve Analysis of Coarse Aggregate

Sieve size (mm)	Weight retained (gm)	Percentage of Weight retained	Percentage Weight of passing	Cumulative percentage of weight Retained
40	0	0	0	200
20	1032.5	103.25	103.25	96.75
12.5	895	89.5	192.75	7.25
10	51.5	5.15	197.9	2.1
4.75	21	2.1	200	0
Total Cumulative percentage of weighted retained				306.1

Fineness Modulus of coarse aggregate = 3.06

2) *Specific Gravity:* The test procedure was same as that of specific gravity of fine aggregate. The Table 5.6 shows the observed reading of specific gravity test on coarse aggregate.

Table Specific Gravity Test of Coarse Aggregate

S. No	Observations	Trial No 1	Trail No 2	Trail No 3
1	Weight of empty container W1 (gm)	458	458	458
2	Weight of container +sample W2(gm)	938	937	1940
3	Weight of container + sample + water W3(gm)	1570	1561	1570
4	Weight of container + water W4 (gm)	1260	1260	1260
5	Specific Gravity	2.85	2.81	2.91

Specific Gravity of Coarse Aggregate = (W2-W1)/[(W2-W1)-(W3-W4)]
Specific Gravity of Coarse Aggregate = 2.85

3) *Water Absorption:* The test procedure was same as that of water absorption of Fine aggregate. The following observation shows the water absorption test for coarse aggregate. Table 5.7 shows the observed reading of water absorption on Coarse aggregate.

Table Water Absorption of Coarse aggregate

S. No.	Observations	Trial No 1	Trial No 2	Trial No 3
1	Weight of sample taken W1(gm)	1000	1000	1000
2	Weight of sample in SSD state W2(gm)	1002.5	1003.15	1001.67
3	Water Absorption	0.23	0.315	0.17

Water absorption of coarse aggregate = {(W2-W1/W1)} x 100
Water absorption of coarse aggregate = 0.3%

4) *Impact test on Coarse Aggregate:* The test sample consists of aggregate sized 10.0mm and 12.5mm. the aggregates passing through 12.5mm sieve and retained on 10mm sieve comprises the test material. The aggregates are poured to fill about 1/3rd depth of the measuring cylinder. The measuring cup is placed in position on the base of machine and compacted by giving 25 gentle strokes with tamping rod. Raise the hammer until its lower face is 380mm above the surface of aggregates sample in the cup and allow to fall freely on the aggregate sample. the crushed aggregate is removed from the cup and sieved through 2.36mm sieve. The fraction passing through the sieve is weighed. The observations on impact values of coarse aggregate is shown in Table.

Table Impact test on Coarse aggregate

S. No.	Observations	Trial No 1	Trial No 2
1	Weight of sample taken W1(gm)	358	345
2	Weight of sample passing 2.36mm sieveW2(gm)	83	76
3	Water Absorption	23	22

Aggregate Impact Value (percent) = W2 / W1 X 100 Impact value of coarse aggregate= 23%

V. MIX PROPORTIONS

A. Mix Proportions for Normal Concrete

Cement = 340 Kg/m3
Fine aggregate = 640 Kg/m3
Coarse aggregate = 1214 Kg/m3
Water – cement ratio = 0.45
Super plasticizer = 6.8 Kg/m3

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Table Mix Ratio

Cement	Fine Aggregate	Coarse Aggregate	Water	Super Plasticizer
1	1.88	3.37	0.45	0.0068

VI. RESULTS AND DISCUSSION

In this chapter, the results of workability, compressive strength, split tensile strength and flexural strength obtained from the experimental study are given in the form of graph and made discussion also.

A. Workability of Concrete

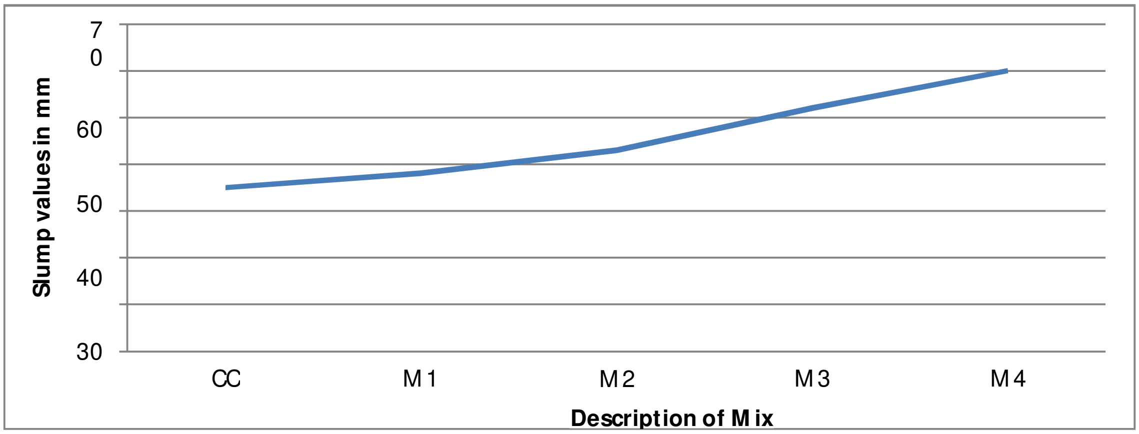

Fig Variation of slump value of concrete using SF & NS

Fig shows the variation of slump value of concrete using micro silica and nanosilica. To increase the workability super plasticizer is added upto 2% of cementitious material.

B. Compressive Strength

Compressive test is the most common test conducted on hardened concrete, partly because it is an easy test to perform, the partly because most of the desirable characteristic properties of concrete are qualitatively related to its compressive strength. The compressive test is carried out on specimens cubical or cylindrical in shape. The cube specimen is of the size 150mm x 150mm x 150mm. The test cube specimens are made as soon as practicable after mixing and such a way as to produce full compaction of the concrete with neither segregation nor excessive laitance.

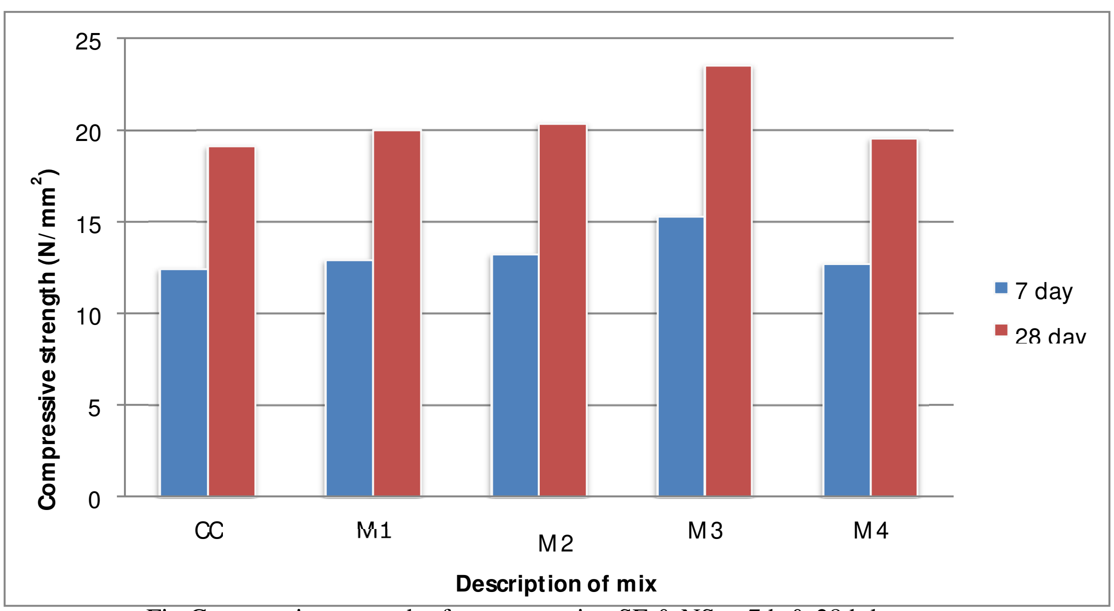

Fig Compressive strength of concrete using SF & NS at 7th & 28thday

Fig shows the compressive strength of concrete using copper slag at 7th and 28th day. The results showed that the compressive strength of concrete is increased in M3 mix (SF 7.5% and NS 1%), beyond that compressive strength was decreases due to increases free water content in the mixes. The excessive free water content in the mixes with silica content causes the bleeding and segregation in concrete. Therefore, it leads reduction in the concrete strength. The highest compressive strength was achieved at 7.5% replacement of cement with micro silica and 1% with nanosilica , which was found about 23.52 N/mm2 which is more than 20% compared to the control mix.

C. Split Tensile Strength

The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack.

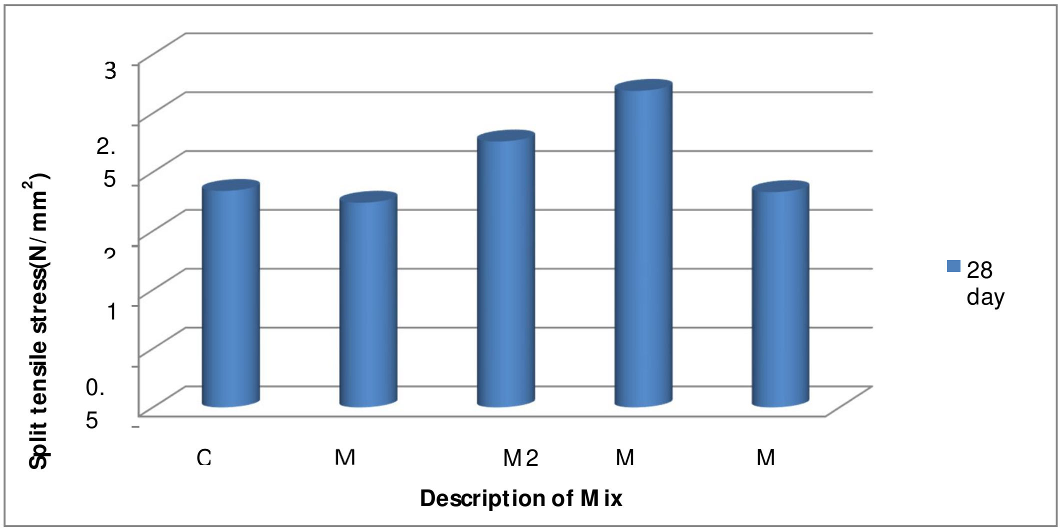

Fig Split tensile strength of concrete using SF & NS at 28th day

Fig shows the split tensile strength of concrete using copper slag at 28th day. The split tensile strength of concrete showed similar behavior to the compressive strength. The results showed that the split tensile strength is increased upto 8.5% replacement of fine aggregate using silica fume and nanosilica, beyond that the split tensile strength value reduced but it more than the split tensile strength of control mix. The results showed that the replacement of fine aggregate using copper slag in concrete increases the tensile strength of about 46.20 % with that of control mixture.

VII. CONCLUSION

Test results obtained in this study indicate that up to 1% nano silica and 7.5% micro silica, could be advantageously blended with cement without adversely affecting the strength. However, optimum levels of these materials are 1~3% nano silica, 3~8% of micro silica in concrete mixes.

Based on experimental results, following conclusion are drawn. It was found that the maximum compressive strength achieved is 23.52 N/mm2 at 7.5% of silica fume and 1% of nanosilica replacement combination. So this strength is greater than the control mix and those achieved for concrete mix name of CM, M1, M2, M3 and M4 is 23 N/mm2,20 N/mm2,20.33 N/mm2,23.52 N/mm2 ,19.55 N/mm2 respectively as compare to strength of plain cement concrete for 28 days .

The optimum split tension strength was obtained at 7.5% of silica fume and 1% of nanosilica in the replacement of cement as 2.69 N/mm2 which is much greater than the control mix and those achieved for concrete mix name as CM, M1, M2, M3 and M4 is 1.84 N/mm2, 1.74 N/mm2, 2.26 N/mm2, 2.69 N/mm2, 1.83 N/mm2 respectively as compare to strength of plain cement concrete for 28 days. The excess addition of silica fume and nanosilica reduces workability. However, in some cases it improves the workability. Silica fume inclusion increases the compressive strength of concrete significantly (6-57%). The increase depends upon the replacement level.

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