International Journal Of Scientific & Engineering Research, Volume 4, Issue 5, May 2013
ISSN 2229-5518

Concrete Composites With Nano Silica, Condensed Silica Fume And Fly Ash – Study of Strength Properties

Abdul Wahab, B. Dean Kumar, M. Bhaskar, S. Vijaya Kumar, B.L.P. Swami

Abstract- Due to the persistent and continuous demands made on concrete to meet the various difficult requirements, extensive and wide spread research work is being carried out in the area of concrete technology. Researchers have developed variants of concrete composites like Admixture Concrete, Fiber Reinforced Concrete (FRC), Polymer Impregnated Concrete (PIC), High Performance Concrete (HPC), Self Compacting Concrete (SCC), Geopolymer Concrete etc. Presently, Nano Technology being applied to concrete includes the use of nano materials like nano silica, nano fibers etc. By adding the nano materials smart concrete composites with superior properties can be produced.

In the present experimental investigation, High Strength Concrete Mixes of M60 and M80 are studied for their mechanical properties. A combination of mineral admixtures like nano silica (nS) and condensed silica fume with OPC is used as replacement to cement in certain proportions and the strength properties are studied. Similarly a combination of nano silica and fly ash with OPC is studied for strength properties. It is found that in the triple blended mixes studied, there is a gradual increase in the strength upto 2 percent of nano silica with 10 percent CSF in the mix and above this there is a gradual decrease in the strengths. Similarly in the combination of fly ash with nano silica with 1.5 percent nS in the mix the strengths are found to be optimum.

Keywords- HPC, Nano Silica, Nano fibres, Liquid emulsion, Microcracks, Triple blending.

1 INTRODUCTION

SEVERAL mineral admixtures like fly ash, Condensed Silica Fume (CSF), Blast Furnance Slag (GGBS), Metakaoline (Mk) etc., are being used as partial replacements to cement to enhance certain properties of cement concrete in the modern day construction. Nano materials are now being introduced as supplementary materials to give additional advantages to concrete.

1.1 Nano Technology in Concrete

Nano Technology applied to concrete includes the use of nano materials like nano silica, nano fibers etc. By adding the nano materials, concrete composites with superior properties can be produced.

Addition of nano silica (nS) in concretes and mortars results in more efficient hydration of cement. Due to the pozzolonic activity, additional calcium silicate hydrates are formed to generate more strength and to reduce free calcium hydroxide. This also helps in reducing the cement requirement, nS improves the microstructure and reduces the water permeability of concrete thus making it more durable. Use of nano silica in HPC and SCC improves the cohesiveness between the particles of concrete and reduces segregation and bleeding. Concretes with strengths as high as 100 MPa with high workability, anti bleeding properties and short demoulding time can be produced. Nano silica can be used as an additive to eco concrete mixtures.

In the case of eco concrete mixtures, industrial wastes such as fly ash, blast furnace slag are used as admixtures at certain percentages as replacement to cement. Certain problems like longer setting time, lower compressive strength at higher percentages can be overcome

by adding nS which improves these properties. Condensed Silica fume (CSF) which is a by product of metallurgical industries when used as a partial replacement to cement (optimum 10 to 15 percent) has been formed to contribute towards strength increase of concrete in addition to other beneficial properties.

1.2 Production of Nano Silica (nS)

Nano materials have atleast one dimension of the order of a nano which is 10^{-9}m. For example one strand of DNA is 2nm wide and human hair has a diameter of nearly 10^{-4}m. A nano particle becomes a quantum dot with dimension of the order of 10nm and this size is so small that jumps in energy levels occur. Nano silica particles are of the same size.

There are different methods to produce nS products. One production method is based on Sol-gel process (organic or water route) at room temperature. In this process, the starting materials like Na_2Sio_4 and organo metallics like TMOS/TEOS are added in a solvent and then the pH of the solution is changed reaching the precipitation of silica gel. The produced gel is mixed and filtered to become a Xerogel. This is further dried and burned or dispersed again with stabilized agent (Na, K, NH_3) to produce a concentrated dispersion (with 20 to 40 % solid content) suitable for use in concrete. There are other methods like vaporization of silica between 1500 to 2000 ºC reducing quartz in an electric arc furnace, biological method, precipitation method etc.

1.3 Benefits of Nano Silica

Addition of nano silica in concretes and mortars results in more efficient hydration of cement. More strength is developed which helps in reducing the cement requirement. Nano silica improves the micro structure and makes concrete more impermeable and more durable. As it produces a dense concrete, compressive strength is increased. In addition, it reduces segregation and bleeding and is ideal for use in High Performance Concrete (HPC) and Self Compacting Concrete (SCC). Further, when self compacting concrete is used in the practical construction, the addition of nS reduces the form work pressure. Addition of nS

- *Abdul Wahab, M.Tech (Struct.), JNTU, College of Engineering, Hyderabad-(A.P)-India E-mail Id: abdulwahab3129@gmail.com*
- *B. Dean Kumar Associate Professor, Civil Engineering Department, JNTU, College of Engineering, Hyderabad-500 085-(A.P), India- E-mail Id: bdeankumar@gmail.com.*
- *M. Bhaskar Associate Professor, Civil Engineering Department, Vasavi College of Engineering, Ibrahimbagh, Hyderabad-31-(A.P),India-E-Mail Id:mbhaskar@gmail.com.*
- *S. Vijaya Kumar, Associate Professor, Civil Engineering Department, Vasavi College of Engineering, Ibrahimbagh, Hyderabad-31-(A.P),India-E-Mail Id:svijayakumar@gmail.com.*
- *B.L.P. Swami Professor, Co-ordination, Research & Consultancy, Civil Engineering,Vasavi College of Engineering, Ibrahimbagh, Hyderabad-500 031(A.P),India-E-mail Id: blpswami@yahoo.com*

also contributes in preventing cracking of concrete at early age in the pavement construction by SCC while using the slip forms.

1.4 Brief Review on the Research work conducted on Nano Silica

Surendra P. Shah et al presented the methods of controlling the properties of concrete through nano technology [(1)], N.P. Rajamane et al [(3)] have studied the application of nS in recycled concrete aggregates.

1.5 Details of the present Experimental Study

The present experimental investigation is mainly carried out to find out the influence of nano silica on concrete composites consisting of other mineral admixtures like silica fume and fly ash. Two triple blended combinations namely (OPC+CSF+nS) and (OPC+Fly Ash+nS) are tried in the present investigation.

2 EXPERIMENTAL INVESTIGATION

2.1 Materials

2.1.1 Cement

OPC (Ultra Tech) 53 grade cement was used in the investigation. The cement was tested for various properties as per the I.S. specifications.

2.1.2 Fine Aggregate (Sand)

Locally available river sand was used.

2.1.3 Coarse Aggregate

Crushed granite metal of 20mm nominal size was used. The fine and coarse aggregates were tested as per the standard specifications.

2.1.4 Condensed Silica Fume (CSF)

Condensed silica fume which is an industrial waste by product was obtained from M/s. V.B.C. Ferro Alloys Ltd., near Hyderabad.

2.1.5 Nano Silica (nS)

Brand	:	CEMSYN-XLP
Active nano content (w/w)	:	14-16%
PH (20^0c)	:	9.3 to 9.6
Specific gravity	:	1.08 to 1.11
Particle size	:	5-10nm

The material was obtained from M/s. Bee Chemists, Kanpur, India.

2.1.6 Fly Ash

Fly Ash was obtained from the Ramagundam Thermal Power Station of Andhra Pradesh.

2.1.7 Superplasticizer

Conplast, 430 of M/s. Fosrock India Ltd., was used wherever found necessary in the experimental investigation.

2.2. Concrete Mix Design

High strength concrete mixes M60 and M80 were designed by the D.O.E. method. The mix proportions are given in table.1.

TABLE-1
CONCRETE MIX PROPORTIONS AND QUANTITIES

Grade of Concrete	M60				M80			
Materials	Cement	Fine Aggr.	Coarse Aggr.	Water	Cement	Fine Aggr.	Coarse Aggr.	Water
Proportions by weight	1	1.07	1.74	0.33 of cement	1	0.864	1.605	0.3 of cement
Quantities required for 1cm	590. 91 Kg.	632.3 5 Kg.	1031.74 Kg.	195 Lit.	650 Kg.	541.7 5 Kg.	1043.2 5 Kg.	195 Lit.

2.3. Proportions of Admixtures

Replacement of cement by the admixtures (both condensed silica fume and nano silica) by various percentages was carried out. The percentages of condensed silica fume were 0,5,10 and 15 where as the percentages of nS were 0, 1, 1.5, 2.0 and 2.5. The percentages of fly ash tried are 0.0, 10 and 20 percents. Thus triple blending was adopted. The various combinations used in the present investigation are given in table.2.

TABLE-2
PERCENTAGE REPLACEMENT OF CEMENT BY SILICA FUME AND NANO SILICA

Mix No.	Silica Fume Percentage	Nano Silica Percentage
1	0	0
2	0	1
3	0	1.5
4	0	2
5	0	2.5
6	5	0
7	5	1
8	5	1.5
9	5	2
10	5	2.5
11	10	0
12	10	1
13	10	1.5
14	10	2
15	10	2.5

2.4 Mixing, Casting, Curing and Testing

The ingredients of each mix of concrete were mixed in the panmixer. Required number of cubes of size 150x150x150mm, cylinders of size 150mm diameters and 300mm height and prisms of size 100x100x500mm were cast. Required number of specimens for each combinations of the mix were cast. The specimens were cured upto a maximum period of 28 days. Mixing, Casting and Curing was carried out as per the standard specifications.

Tests were conducted for workability on fresh concrete, compressive strength, split tensile strength and flexural strength on hardened specimens. Standard procedures were adopted for testing.

3 DISCUSSION OF THE RESULTS

The results of the experimental investigations are presented and discussed herein.

The compressive strength results with CSF and nS are given in Table 3&4 for M60 & M80 grades of concrete. Table 5&6 give the compressive results of Flyash with nano silica.

3.1 Workability of high strength concrete mixes with Nano Silica and CSF

In the present project work, the mineral admixture CSF is much finer than cement and as such its water demand is also more. Hence, when both nano silica and CSF are used in high strength concrete mixes, the workability is getting very adversely affected.

When concrete mixes with these admixtures are prepared during the experimental work, superplasticizer (Conplast SP-430) has been added upto 2% so as to give workable mixes for the preparation of test samples. Hence, it can be stated that adequate quantities of superplasticizers are to be added when admixtures like nano silica and CSF are used along with cement in high strength concrete mixes.

3.2 Compressive Strength Results

3.2.1 General Effect of Nano Silica

With 0% nano silica the basic M60 concrete has given the design strength of 63.64 MPa at 28 days and with 1% nano wilica the strength has gone upto 65.22 MPa. There is gradual increase in compressive strength upto 2% where the value is 68.78 MPa. Thus there is an increase of 5.14 MPa which is equal to nearly 8%. Beyond 2% nano silica, the strength is coming down and the recorded value is 59.80 MPa for 2.5% nano silica. Similarly in case of concrete mix M80 same trend is observed. At 2% nano silica, there is an increase of nearly 5% in compressive strength. Hence, 2% nano silica appears to be the optimum in present conditions.

3.2.2 Effect of nS and CSF on the compressive strength

To further increase the strength properties of concrete combination of nano silica with CSF is tried in the present project work. With 0% nano silica and 0% CSF the basic M60 concrete has given design strength of 63.64 MPa at 28 days, with 2% nano silica and 0% CSF the strength is going upto 68.78 MPa and with 2% nano silica and 10% CSF the strength is further going upto 70.92 MPa. Similarly in the case of concrete mix M80 same trend is observed. Hence, out of these combinations the highest strength is obtained with 2% nano silica and 10% CSF in the present conditions. The compressive strength results are given in tables 3 & 4.

TABLE-3
COMPRESSIVE STRENGTH FOR M60

S.No.	Mix Designation	Cement %	CSF %	Nano Silica %	Ultimate Compressive Strength (N/mm^2)
1	N_{600}	100	0	0	63.64
2	N_{601}	99	0	1	65.22
3	$N_{601.5}$	98.5	0	1.5	66.40
4	N_{602}	98	0	2	68.78
5	$N_{602.5}$	97.5	0	2.5	59.80
6	N_{650}	95	5	0	65.92
7	N_{651}	94	5	1	65.98
8	$N_{651.5}$	93.5	5	1.5	66.65
9	N_{652}	93	5	2	69.56
10	$N_{652.5}$	92.5	5	2.5	62.52
11	N_{610}	90	10	0	68.78
12	N_{611}	89	10	1	68.96
13	$N_{611.5}$	88.5	10	1.5	69.54
14	N_{612}	88	10	2	70.92
15	$N_{612.5}$	87.5	10	2.5	64.58

TABLE-4
COMPRESSIVE STRENGTH FOR M80

S. No.	Mix Designation	Cement %	CSF %	Nano Silica %	Ultimate Compressive Strength (N/mm^2)
1	N_{800}	100	0	0	84.64
2	N_{801}	99	0	1	84.92
3	$N_{801.5}$	98.5	0	1.5	86.22
4	N_{802}	98	0	2	87.81
5	$N_{802.5}$	97.5	0	2.5	76.84
6	N_{850}	95	5	0	86.84
7	N_{851}	94	5	1	87.20
8	$N_{851.5}$	93.5	5	1.5	87.70
9	N_{852}	93	5	2	88.84
10	$N_{852.5}$	92.5	5	2.5	80.74
11	N_{810}	90	10	0	87.61
12	N_{811}	89	10	1	88.10
13	$N_{811.5}$	88.5	10	1.5	88.52
14	N_{812}	88	10	2	88.91
15	$N_{812.5}$	87.5	10	2.5	82.65

TABLE-5
COMPRESSIVE STRENGTH FOR M60 (WITH FLY ASH AND NANO SILICA)

S.No.	Mix Designation	Cement %	Fly ash	Nano Silica%	Ultimate Compressive Strength (N/mm^2)
1	M_{600}	100	0	0	61.8
2	M_{601}	99	0	1	68.75
3	$M_{601.5}$	98.5	0	1.5	68.96
4	M_{602}	98	0	2	63.3
5	$M_{602.5}$	97.5	0	2.5	59.8
6	M_{610}	90	10	0	61.4
7	M_{611}	89	10	1	62.6
8	$M_{611.5}$	88.5	10	1.5	64.5
9	M_{612}	88	10	2	64.5
10	$M_{612.5}$	87.5	10	2.5	57.8
11	M_{620}	80	20	0	60.6
12	M_{621}	79	20	1	61.4
13	$M_{621.5}$	78.5	20	1.5	63.2
14	M_{622}	78	20	2	61.4
15	$M_{622.5}$	77.5	20	2.5	57.0

TABLE-6
COMPRESSIVE STRENGTH FOR M80 (WITH FLY ASH AND NANO SILICA)

S.No.	Mix Designation	Cement %	Fly ash	Nano Silica%	Ultimate Compressive Strength (N/mm^2)
1	M_{800}	100	0	0	85.7
2	M_{801}	99	0	1	81.5
3	$M_{801.5}$	98.5	0	1.5	88.2
4	M_{802}	98	0	2	89.3
5	$M_{802.5}$	97.5	0	2.5	79.3
6	M_{810}	90	10	0	80.6
7	M_{811}	89	10	1	85.3
8	$M_{811.5}$	88.5	10	1.5	88.8
9	M_{812}	88	10	2	87.4
10	$M_{812.5}$	87.5	10	2.5	76.6
11	M_{820}	80	20	0	80.0
12	M_{821}	79	20	1	84.3
13	$M_{821.5}$	78.5	20	1.5	85.9
14	M_{822}	78	20	2	87.8
15	$M_{822.5}$	77.5	20	2.5	75.4

3.2.3 Effect of nS and Fly ash on Compressive Strength

From the results of fly ash, nano silica combinations with OPC, it can be seen that 1.5 percent of nano silica with any fly ash percentage is giving the highest compressive strength. As the percentage of fly ash in the mix is increased, the strength is getting decreased. Fly ash with nano silica is not contributing to strength increase. However fly ash imparts other beneficial properties to the concrete composite.

3.3 Split Tensile Strength Results

With 0% nano silica and 0% CSF the basic M60 concrete has given design strength of 6.01 MPa at 28 days. With 2% nano silica and 0% CSF the strength is going upto 6.42 MPa and with 2% nano silica and 10% CSF the strength is further going upto 6.85 MPa. Similarly in the case of concrete mix M80, same trend is observed. Hence out of these combinations, the highest strength with 2% nano silica and 10% CSF is obtained. These are given in tables 5 & 6. The split tension results are also plotted in fig.1 & 2.

As in the case of compressive strength, the split tensile strength also follows the same pattern. Highest strength for M60 and M80 mixes are obtained with 1.5 percent of nano silica with fly ash. Fly ash has no influence on the strength, except that the optimum percentage of nano silica has been reduced from 2 percent to 1.5 percent in the presence of fly ash.

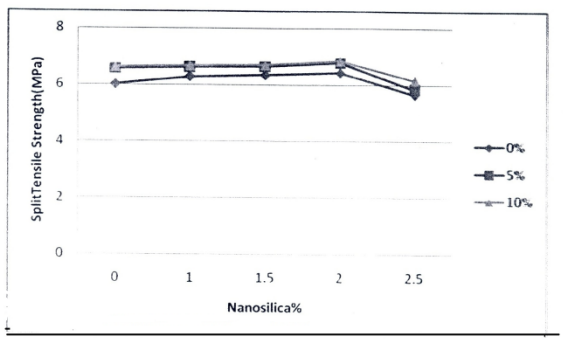

Fig.1 : Variation of split tensile strength with percentage of nano Silica for different CSF percentages for M60 concrete

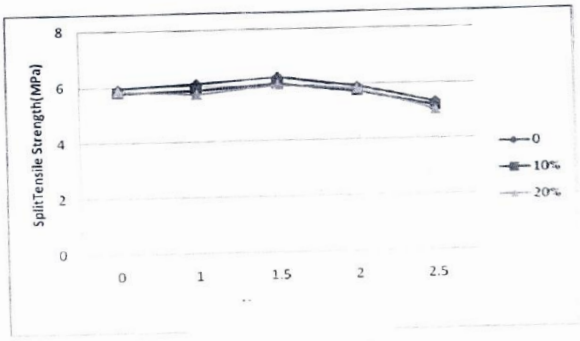

Fig.2: Variation of split tensile strength with percentage of nano silica for different Flyash percentages for M60 concrete

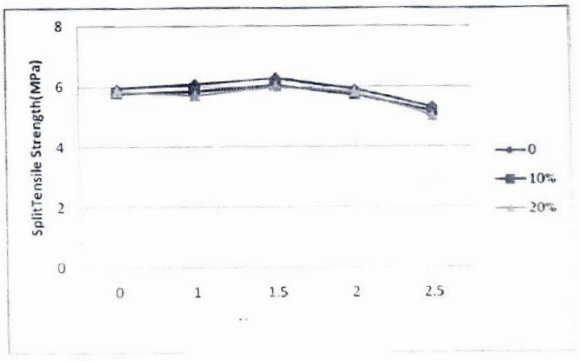

Fig.3: Variation of Flexural Strength with percentage of Nano Silica for different Flyash percentages for M60 concrete

3.4 Flexural Strength Results

With 0% nano silica and 0% CSF the basic M60 concrete has given design strength of 6.42 MPa at 28 days. With 2% nano silica and 0% CSF the strength is going upto 6.72 MPa and with 2% Nano Silica and 10% CSF the strength is further going upto 6.94 MPa. Similarly in the case of concrete mix M80, same trend is observed. Hence, out of these combinations, the highest strength with 2% nano silica and 10% CSF is obtained in the present conditions. Flexural Strength results are also plotted in fig.3.

Same trend in the flexural strength results is observed in M60 and M80 mixes. As already discussed 2 percent nano silica with 10 percent CSF is giving the optimum strength. In the case of fly ash nano silica mixes 1.5 percent nS with no fly ash is giving the highest strength.

4 CONCLUSIONS

Based on the present experimental investigation, the following conclusions are drawn.

1. It can be stated that adequate quantities of super plasticizers are to be added when admixtures like nano silica and CSF are used along with cement in high strength concrete mixes. While using the nano silica solution in concrete the original water cement ratio of concrete mix is to be corrected by the amount of water available in nano silica solution.

2. 2% nano silica appears to be the optimum in the high strength concrete mixes like M60 and M80 without any admixtures. The highest compressive strength with 2% nano silica and 10% CSF appears to be the optimum in the present triple blended concrete mixes.

3. In the case of split tensile strength 2% nano silica gives the highest value without any admixture. The highest strength with 2% nano silica and 10% CSF appears to be the optimum in present conditions for split tensile strength.

4. In the case of flexural strength 2% nano silica gives the highest value without any admixture.

5. In the case of fly ash, nano silica, concrete mixes, the presence fly ash does not contribute towards any strength increased. In these mixes, 1.5 percent nano silica is giving the optimum strength without fly ash. However, replacement of cement by an admixtures like fly ash would leave other beneficial properties besides economi.

6. With introduction of nano materials like nano silica and fibres in concrete it is expected that better composites of concrete can be prepared to answer any kind of situation faced by the structures.

ACKNOWLEDGEMENT

The authors thank the authorities of Vasavi College of Engineering, Ibrahimbagh, Hyderabad, for the help rendered for conducting the experimental investigation.

REFERENCES

1. A.K. Mullick “Performance of with Binary cement blends” the Indian Concrete Journal, January 2007.

2. Surenra P. Shah, et al. “Controlling Properties of Concrete through Nano Technology” (ACBM Centre, North Western University, USA), Proc. of the International Conference on advances in Concrete, ICI-ACECON 2010, 5-9 Dec., IIT, Madras, India, PP 1-8.

3. G. Quercia and H.I.H. Browwers, ‘Applications of Nano Silica in Concrete Mixtures’, 8th Ph.D. Symposium in Kgs Lyngby, Denmark, June 20-23, 2010.

4. Swupnan Kutchnhapati and N.P. Rajamane, ‘Nano Silica improves Recycled Concrete Aggregates’ Proc. of Third Editions of Workshop on Engineering Materials and its Applications (WEMA), held on 2nd Dec., 2010 at AVIT, Chennai.

5. Bee Chems ‘Nano Silica Base additives for Cementing Operations’ E-5 Puski Industrial Area, Site-1, Kanpur (U.P)-208022 (INDIA).

6. N. Neelamegam, J.K. Dattatreya and S. Goplakrishna “Pore structure effects in properties of concrete with Binary and Ternary Blends” International Conference in Advances in Concrete Composites and Structures, 83-90.