COMPARATIVE STUDIES ON HIGH STRENGTH CONCRETE MIXES USING MICRO SILICA AND NANOSILICA

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Abstract— **In present day constructions concrete is chosen as one of the best choices by civil engineers in construction materials. The concept of sustainability is touching new heights and many green building materials are tried and tested as partial replacement for the cement. One of the bye-products is Condensed Silica Fume (CSF) which enhances the durability and strength of the concrete. In the present investigation the strength of M60 and M70 concretes with the use of micro silica and in combination with colloidal nano-silica was used to study the mechanical properties. It is found from the experimental investigation that concrete composites with superior properties can be produced with the combination of micro-silica and nano-silica.**

Index Terms— **Natural aggregate, Colloidal nano-silica (nS), Condensed Silica Fume (CSF), Compressive Strength, Split Tensile Strength, Flexural Strength.**

I. INTRODUCTION

Concrete is the material of choice where strength, performance, durability, impermeability, fire resistance and abrasion resistance are required. The hunger for the higher strength leads to other materials to achieve the desired results and thus emerged the contribution of cementitious material for the strength of concrete. Addition of pozzolonic admixture like the pulverised Fly ash (PFA) or condensed silica fume (CSF) which helps in the formation of secondary C-S-H gel contributes to the improvement of strength. By adding the nano materials, concrete composites with superior properties can be produced. Nano Technology applied to concrete includes the use of nano materials like nano-silica, nanofibers etc. (Sobolev and Gutiérrez 2005; Gammampila, Mendis et al. 2010). 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. Nano-silica improves the microstructure and reduces the water permeability of concrete thus making it more dense and durable (Shamsai, Perotiet at. 2012). Nano-silica can be used as an additive to eco concrete mixtures. In the case of eco concrete mixtures industrial wastes such as flyash, blast furnace slag are used as admixtures at certain percentages as replacement to cement. Use of nano-silica in HPC and SCC improves the cohesiveness between the particles of concrete and reduces segregation and bleeding. (Collepardi, Collepardi et al. 2004). Certain problems like longer setting time, lower compressive strength at higher percentages can be overcome by adding nano- silica which improves these properties.The addition of pozzolonic admixture like the PFA will reduce the strength gain for the first 3 to 7 days of concrete but will show gain beyond 7 days and gives a higher strength over long term. With the addition of highly reactive pozzolonic admixtures like the CSF will start contributing in about 3 days and nano-silica will start contributing after one day(Nili, Ehsani et al. 2010). The present investigation is carried out to study the strength properties of high strength concrete mix of M60 and M70 grades, with a partial replacement of cement with CSF and nano-silica with the concept of triple blending of cement with CSF and nano-silica.

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II. EXPERIMENTAL WORK

The main objective of this paper is to compare the hardened properties of concrete made with triple blending of cement with CSF and nano-silica.

A. MATERIALS USED

Cement

The Ordinary Portland Cement (OPC) of 53 grade confirming to Indian standard IS 12269-1987 was used.

Fine aggregate

Fine aggregate used for this entire study of investigation for concrete was river sand confirming to zone-3 of IS: 383-1970.

Coarse aggregate

Crushed hard granite chips of maximum size 20mm were used in concrete mixes.

Water

Potable water confirming to IS: 456-2000 was used for casting and curing.

Condensed Silica Fume

The CSF was obtained from M/s V.B. Ferro Alloys Pvt.Ltd., Hyderabad. The specific surface area is 15000 cm^2/gm and the silica content is about 70%.

Nano Silica

CemSyn®-XLP,is a series of silica based binders /fillers obtained from Bee-chem Chemicals Ltd., Kanpur.

State - Dispersed in water
Active nano Content (%W/W) -14-16%
pH (20°c) - 9.3-9.6
Specific gravity - 8-1.11
Particle size - 5-10 nm

Super Plasticizer

Fosroc CONPLAST SP430 Aqueous solution of Sulphonated Naphthalene Formaldehyde Condensates was used.

B. *Mix Design*

The control mixes were made for M60 and M70 grade concretes. The various ingredients used in the mixes are as per table-1.

C. *CASTING OF SPECIMENS*

Casting of Specimens was done by batching of materials, preparation of moulds and placing of concrete in the moulds.

D. *BATCHING*

A proper mix of concrete is essential for the strength of the concrete. Before the concreting, all the mix material were weighedand kept ready for concreting as per design mix proportions.

E. *PREPARATION OF CONCRETE MOULDS*

Concrete moulds were oiled for easy stripping. The moulds for conducting tests on fresh concrete were made ready and inner surfaces were oiled.

F. *PREPARATION OF CONCRETE*

Concrete was mixed in the pan mixer and dumped in a metal tray placed on a flat surface.

G. *TESTS ON FRESH CONCRETE*

Super plasticizer was used at 1.5% by weight of Cement and Compacting factor was found to be at 0.85 when the CSF and nS limit is 2% and when the Nano silica has exceeded 2% the mix is found to be not cohesive.

H. *PREPARATION OF SAMPLES*

During the placing of fresh concrete into mould, proper care was taken to remove entrapped air by using a table vibrator to attain maximum strength. Vibrator was used after every 1/3 filling of material into the mould and the top surface was properly levelled at the end.

I. *DEMOULDING*

After levelling the fresh concrete in the moulds, it was allowed to dry for 24 hrs. The identification marks of concrete specimens were done with permanent markers and the specimens were removed from the moulds. The moulds were cleaned and kept ready for next batch of concrete mix.

J. *CURING*

Curing is an important process to prevent the concrete specimens from losing their moisture while they are gaining their required strength.. All concrete specimens were cured in water at room temperature for 7 and 28 days. After curing, concrete specimens were removed from the curing tank and air dried to conduct tests on hardened concrete.

III. TESTS CONDUCTED ON HARDENED CONCRETE

A. *Compressive strength*

Three specimens of size 100 mm x 100 mm x 100 mm were used for compression testing for each batch of mix. Clean and surface dried specimens were placed in the testing machine. The platen was lowered and touched the top surface of the specimen, the load was applied gradually and maximum load was recorded (Plate No.1).

B. *Split Tensile strength Test*

Split tensile test was conducted on cylinders of size 150mm diameter and 300mm height. Clean and surface dried specimens were placed in the testing machine. The platen was lowered and was allowed to touch the top surface of the specimen. The force was applied and maximum load at which the specimen failed was recorded.

C. *Flexural strength*

The prisms were tested to evaluate the flexural strength of the concrete by two point loading. The prism dimensions were measured accurately before testing and marked before testing for placing in exact position (Plate No.2).

The test results on hardened concrete are reported in Table No. 2.

IV. DISCUSSIONS OF RESULTS

The results obtained from the experimental investigations are tabulated in table 3. The results have been analyzed and the graphs showing the strength variations are plotted. The effect of partial replacement of cement with CSFand nano-silica isdiscussed herein.

A. *Compressive Strength*

1.1. It has been observed that with addition of CSFand the compressive strength of concrete at 7 days and 28 days are more than that of controlled specimens (Tables 2 & 3).

1.2. It has been observed that the compressive strength of concrete at 7 days and 28 days are maximum with 10% CSF and 2%Nano silica combination.

1.3. It has been observed that compressive strength of concrete with 2%nano-silica is nearly same as with 5% CSF.

1.4. With the partial replacement of cement by 10% CSFand 2% nano-silica, the compressive strength at 28 days, is increased by 14.01% and 7.41% for M60 and M70 concretes respectively. Typical compressive strength results are also illustrated by the bar chart (Fig. 1.1) for M60 grade concrete.

B. Flexural Strength

1.1. It is observed that with addition of CSFand nano-silica the flexural strengths of concrete at 7 days and 28 days are more than that of controlled specimens (Table 2 and 3).

1.2. The flexural strengths of concrete at 7 days and 28 days are maximumwith 10% CSF and 2% nano-silica combination.

1.3. With the partial replacement of cement by 10% CSFand2%nano-silica the flexural strength at 28days , is increased by 2.4% for M60, and 7.5% for M70. Typical results for M60 grade concrete are also illustrated by bar chart (fig. 2.1)

C. Split Tensile Strength

1.1. It has been observed that with addition of CSFand nano-silica the split tensile strength of concrete at 7 days and 28 days are more than that of controlled specimens (Table.2 &3).

1.2. The split tensile strengths of concrete at 7 days and 28 days are maximumwith 10% CSF and 2%nano-silica combination.

1.3. Thepartial replacement of cement by 10% CSF and 2%nano-silica has increased the split tensile strength at 28days, is increased by 13.04%for M60 and 10.24%forM70 than control concrete.

1.4. Typical results for M60 concrete are also illustrated by bar chart (fig 3.1).

D. *It has also been observed that for combination of 4% nano-silica the strength is decreased as the dosage might have been crossed the optimum level.*

V. Conclusion

Based on the experimental studies conducted the following conclusions are drawn.

1. The compressive strength of concrete had shown an increasing trend with the increase in the quantity of CSF but the increment was stopped when the nSwas beyond 2% and CSF was beyond 10%.
2. The percentage increase in compressive strength and split tensile strength of concrete with the combination of CSF at 10% and nS at 2% is 14% more compared to control concrete.
3. The increase in flexural strength is only 2% compared to control concrete.
4. The strength of concrete has drastically decreased by 50% when the nS is at 4% and this indicates the crossing of optimum usage of nS in concrete for the present nS solution used where the concentration of nS is 15%.

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References

1. IS: 2386 (Part III) -1963,Methods of Test for Aggregates for Concrete: Specific Gravity, Density, Absorption and Bulking.
2. IS: 2386 (Part IV) -1963, Methods of Test for Aggregates for Concrete: Mechanical properties.
3. IS: 516 -1963, Method of Test for Strength of Concrete
4. Collepardi, M., S. Collepardi, et al. (2004). Optimization of silica fume, fly ash and amorphous nano-silica in superplasticized high-performance concretes. Proceedings of 8th CANMET/ACI International Conference on Fly Ash, Silica Fume, Slag and Natural Pozzolans in Concrete, SP-221, Las Vegas, USA.
5. Gammampila, R., P. Mendis, et al. (2010). Application of Nanomaterials in the Sustainable Built Environment.
6. Nili, M., A. Ehsani, et al. (2010). Influence of Nano-SiO2 and Microsilica on Concrete Performance. Second International Conference on Sustainable Construction Materials and Technologies, Università Politecnica delle Marche, Ancona, Italy, Coventry University and The University of Wisconsin Milwaukee Centre for By-products Utilization.
7. Shamsai, A., S. Peroti, et al. (2012). "Effect of Water-Cement Ratio on Abrasive Strength, Porosity and Permeability of Nano-Silica Concrete." World Applied Sciences Journal **17**(8): 929-933.
8. Sobolev, K. and M. F. Gutiérrez (2005). "How nanotechnology can change the concrete world." American Ceramic Society Bulletin **84**(10): 14.

Table-1 Summary of Mix proportions as per (DOE METHOD)

Designation	Mix	w/c ratio	Water (litre)	Cement (kg)	NA (kg)	Fine aggregate(kg)	Mix design
A	M60	0.33	195	591	1032	632	1: 1.070: 1.746 @ 0.33 w/cm
B	M70	0.30	195	650	1043	562	1:0.864:1.605 @ 0.3 w/cm

Table-2:Test Results of M60 grade concrete at 7 and 28 days

M60 grade Concrete								
S.No.	%CSF	% NS	Compressive strength		Flexural strength		Split tensile strength	
			7days	28days	7 days	28 days	7 days	28 days
A00	0	0	42.42	63.64	4.36	5.82	4.35	5.75
A02	0	2	45.85	68.78	4.37	5.83	4.33	5.85
A04	0	4	31.85	47.78	2.01	2.21	2.87	3.51
A50	5	0	45.85	68.78	4.42	5.9	4.42	5.93
A52	5	2	47.28	70.92	4.44	5.92	4.63	6.21
A54	5	4	32.43	48.64	2.53	2.61	3.03	3.98
A100	10	0	47.28	70.92	4.44	5.93	4.65	6.2
A102	10	2	48.37	72.56	4.47	5.96	4.87	6.5
A104	10	4	35.01	52.52	2.78	3.12	3.12	4.17

TABLE 3:Test Results of M70 grade concrete at 7 and 28 days

M70 grade concrete								
S.No	%CSF	% NS	Compressive strength		Flexural strength		Split tensile strength	
			7days	28days	7 days	28 days	7 days	28 days
B00	0	0	55.76	83.64	4.75	6.32	4.60	6.15
B02	0	2	58.4	87.81	4.59	6.13	4.53	6.01
B04	0	4	44.56	66.84	2.08	3.2	3.21	4.31
B50	5	0	57.07	85.61	4.85	6.47	4.65	6.23
B52	5	2	59.27	88.91	4.95	6.6	4.94	6.55
B54	5	4	45.77	68.65	2.54	3.57	3.45	4.64
B100	10	0	57.89	86.84	4.92	6.56	4.84	6.49

B102	10	2	59.89	89.84	5.1	6.8	5.06	6.78
B104	10	4	47.16	70.74	2.88	3.98	3.61	4.85

Plate 1.Compression Test

Plate 2. Flexure Test

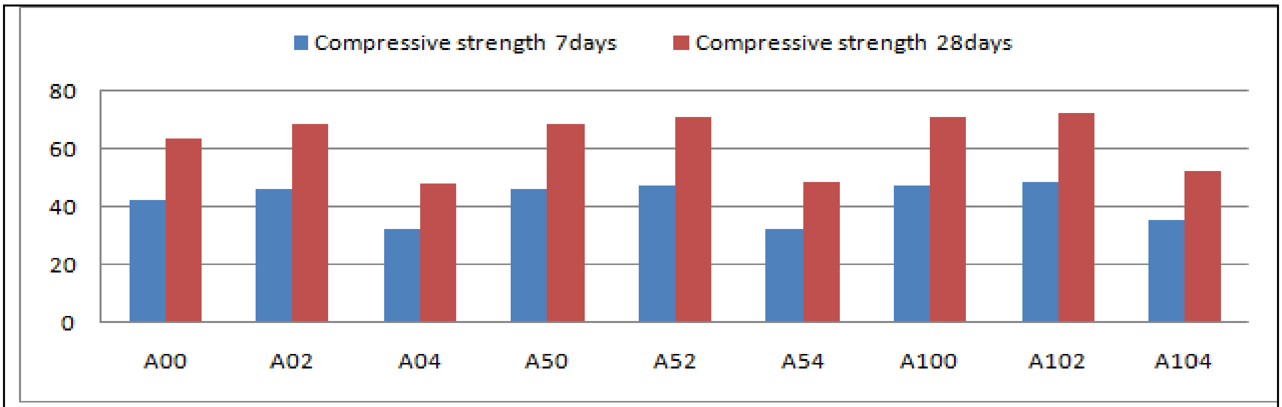

Fig.1.1.Variation of compressive Strength of M60 grade Concrete

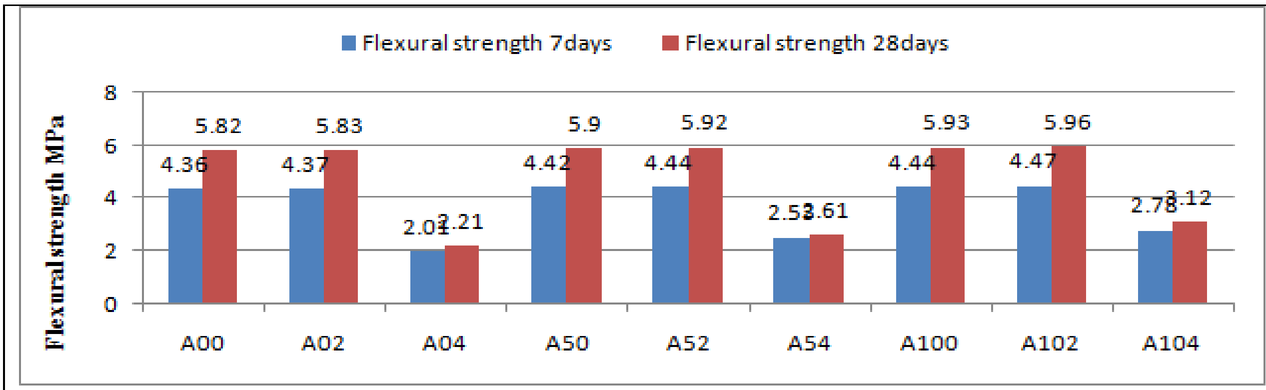

Fig.2.1.Variation of Flexural Strength of M60 grade Concrete

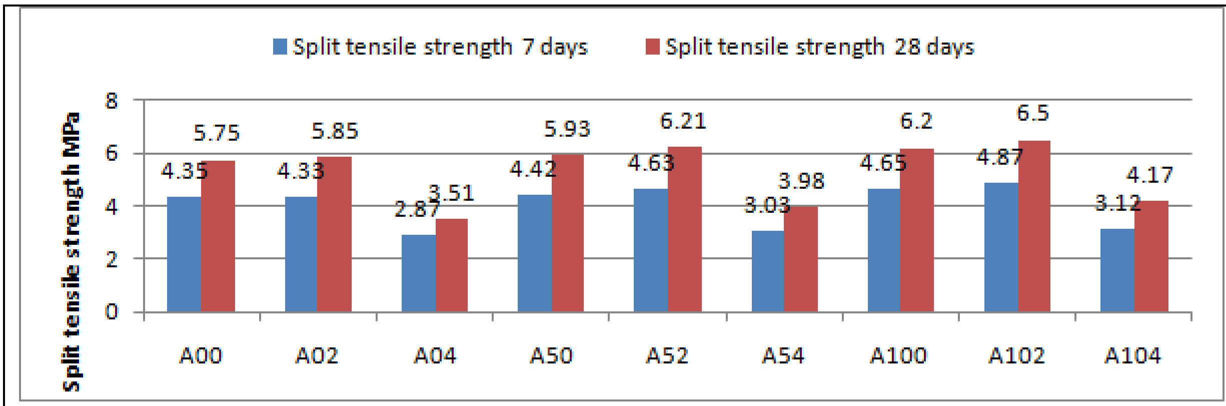

Fig.3.1.Variation of Split Tensile Strength of M60 grade Concrete

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