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Effects on the Particular Shape of Concrete on Addition of Silica Fumes

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Abstract:
Concrete is the most versatile construction material because it can be designed to withstand the harshest environments while taking on the most inspirational forms. Engineers are continually pushing the limits to improve its performance with the help of innovative chemical admixtures and supplementary cementitious materials. Nowadays, most concrete mixture contains supplementary cementitious material which forms part of the cementitious component. These materials are majority by products from other processes. The tests conducted on it shows 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 nano silica. The FESEM micrographs support the results and show that the microstructure of the hardened concrete is improved on addition of nano silica.

INTRODUCTION

BACKGROUND

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 has to 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 flyash, 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.

OBJECTIVE OFTHESTUDY

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

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

SCOPE OF WORK

The present study in corporate mix design based on the guidelines as per Indian Standard code IS 10262-2009. The nano-silica 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 nano-silica was identified using Particle Size Analyser.

ORGANIZATION OF THE THESIS

This thesis has been organised into five chapters as shown below:

i. The first chapter is the 'Introduction' which gives an idea of the theory involved and the importance of the present work. This is the ongoing chapter.

ii. A'Review of Literature'follows this chapter which gives an understanding of the various work carried on this field by different authors.

iii. The third chapter ,'Materials and Methods' explains all the material properties and methods used in the experiment.

iv. The fourth chapter, 'Experimental Evidence and Microstructure Analysis' deals with the experimental results of various tests carried on concrete, the FESEM analysis, the PSA analysis and a comparative analysis of the results with the help of tables and graphs.

v. The last chapter, 'Conclusion and Discussion' summarizes the results and interpretations of the study and also states the limitations of the work and the scope for future work.

REVIEW OF LITERATURE

In this chapter the works of various authors on the use of nano materials in concrete has been discussed in brief. A great number of researches have been performed to understand the nature of nano materials and their effect on the properties of concrete. A number of Research & Development work dealing with the use of nano materials like Nano silica,colloidal Nano Silica (CNS), Al_2O_3 ,TiO_2, ZrO_2, Fe_2O_3, carbon nano tubes (CNT) in cement based materials are discussed in the literature. The pozzolanic activity of the material is essential in forming the C-S-H gel and hence the CH crystals are prevented from growing and their number reduces.Thus the early age strength of hardened cement paste is increased. A comparative analysis of this work has been presented in the summary of this chapter which will highlight the significance of each work. Out of the numerous work done in the field only a few relevant works have been highlighted in the next section.

Alirza Naji Giviet.al.(2010) studied the size effect of nano silica particles.They replaced cement with nano silica of size 15nm and 80 nm with 0-5,1,1.5&2 % b.w.c. An increase in the compressive strength was observed with 1.5% b.w.c showing maximum compressive strength. A comparison between particle size showed that for 80 nm particles the maximum strength was more than for 15 nm particles, also a considerable improvement in flexural and split tensile strength of Nano SiO2 blended concrete was observed.

A.Sadrmotaziet.al.(2010),in an other paper,have studied the effect of PP fiber along with nano SiO2 particles. The nano silica was replaced up to 7% which improved the compressive strength of cement mortar by 6.49 %. PP fiber amounts beyond 0.3% reduces the compressive strength but beyond 0.3% dose of PP fiber increases the flexural strength, showing the effectiveness of nano SiO2 particles. Also up to 0.5% PP fibers in mortar water absorption decreases which indicates pore refinement.

Ali Nazari et.al. (2010) studied the combined effect of Nano SiO2 particles and GGBFS on properties of concrete. They used nano silica with 3% b.w.c.replacement and 45% b.w.c. GGBFS, which shows improved split tensile strength. An improvement in the pore structure of SCC with silica particles was observed. Apart from this hey have studied the effect of ZnO2 nano particles on SCC concrete with constant w/c ratio of 0.4. The results showed that by increasing the content of superplasticizer flexural strength decreases. Upto 4 % b.w.c. of ZnO2 content an increase in the flexural strength of SCC was recorded. In another experiment the same author studied effect of Al2O3 nano particles on the properties of concrete. The results showed that cement could be replaced up to 2% for improving mechanical properties of concrete, but Al2O3 nano particles decreased percentage water absorption of concrete. XRD analysis of the sample showed that there is more rapid formation of hydrated product.

M.Collepardiet.al.(2010) studied the effect of combination of silica fume, fly ash and ultra fine amorphous colloidal silica (UFACS) on concrete. The result shows that steam cured concrete containing SF and FA alone are much stronger than NC cured at room temperature at early age where as compressive strength at 28-90 days of steam cured concrete is less than NC cured at room temperature. So author advised to use SF, FA&UFACS for the manufacturing of precast unit.

M.S. Morsy et. al. (2010) studied the effect of nano-clay on the mechanical properties and microstructure of Portland cement mortar and observed that the tensile and compressive strength increased by 49% and 7% respectively at 8% nano-metakaolin (NMK).

Surya Abdul Rashid et.al.(2011) worked on the effect of Nano SiO2 particle on bothmechanical properties (compressive, split tensile and flexural strength) and physical properties (water permeability, workability and setting time) of concrete which shows that binary blended concrete with nano SiO2 particles up to 2%has significantly higher compressive, split tensile and flexural strength compared to normal concrete. Another inference drawn was that partial replacement of nano SiO2 particles decreases the workability and setting time of fresh concrete for samples cured in lime solution.

Ali Nazari et.al. (2011) studied strength and percentage water absorption of SCC containing different amount of GGBFS and TiO2 nano particles.The findings of the experimentation are that replacement of Portland cement with up to 45% weight of GGBSF and up to 4% weight of TiO2 nanoparticles gives a considerable increase to the compressive, split tensile and flexural strength of the blended concrete. This increase is due to more the formation of hydrated products in presence of TiO2;also the water permeability resistance of hardened concrete was improved.The author also studied effect of CuO nano particles on SCC and observed that increased percentage of polycarboxylate admixture content results in decreased compression strength. The CuO nano particles of average particle size 15nm content with up to 4% weight increased the compressive strength of SCC. CuO nano particles up to 4% could accelerate the first peak in conduction calori metric testing which is related to the acceleration of formation of hydrated cement products.

Sekari and Razzaghi (2011) studies the effect of constant content of Nano ZrO2, Fe2O3, TiO2, and Al2O3 on the properties of concrete. The results showed that all the nano particles have
Notice able influence on improvement on durability properties of concrete but the contribution of nano Al2O3 on improvement of mechanical properties of HPC is more than the other nano particles.

A.M.Saidet.al.(2012) studied the effect of colloidal Nanosilica on concrete by blending it with class F fly ash and observed that performance of concrete with or without fly ash was significantly improved with addition of variable amounts of nano silica. The mixture containing 30% FA and 6% CNS provides considerable increase in strength. Porosity and threshold pore diameter was significantly lower for mixture containing Nano silica. The RCPT test shows that passing charges and physical penetration depth significantly improved.

Alireza Naji Givi et.al. (2012) studied the effect of Nano SiO2 particles on water absorption of RHA blended concrete. It is concluded that cement could be replaced up to 20% by RHA in presence of Nano SiO2 particle up to 2% which improves physical and mechanical properties of concrete.

Heidari and Tavakoli (2012) investigated the combined effect of replacement of cement by ground ceramic powder from 10% to 40% b.w.c. and nano SiO2 from 0.5 to 1%. A substantial decrease in water absorption capacity and increase in compressive strength was observed when 20% replacement is done with ground ceramic powder with 0.5 to 1% as the optimum dose of Nano SiO2 particles.

SUMMARY

The review of a number of literatures shows the importance of this field of research.The findings shows that a number of nano materials like SiO_2, TiO_2, Al_2O_3, colloidal nano silica, metakaolin and others can be incorporated to improve the properties of concrete. The results show the

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improved characteristics of the blended concrete in terms of compressive, tensile and flexural strength. Apart from that the permeability of the specimen can also be increased by adding a small percentage of the nano material. The SEM, XRD and other analysis shows an improved microstructure with reduced number of pores.
The current study is concerned with the in corporation of Nano SiO_2 only.

MATERIALS AND METHODS

GENERAL

This chapter is concerned with the details of 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.

MATERIAL PROPERTIES

The materials used to design the mix for M25 grade of concrete are cement, sand, coarse aggregate, water and Nano SiO_2. The properties of these materials are presented below.

Properties of Cement

Portland slag cement of 43 grade conforming to IS: 455-1989 is used for preparing concrete specimens. The properties of cement used are given in the Table 2.

Table3.1: Properties of Portland slag cement

Specific Gravity	Fineness by sieve analysis	Normal consistency
3.014	2.01%	33%

Properties of fine and coarse aggregate

Sand as fine aggregates are collected from locally available river and the sieve analysis of the samples are done. It is found that the sand collected is conforming to IS: 383-1970. For coarse aggregate, the parent concrete is crushed through mini jaw crusher. During crushing it is tried to maintain to produce the maximum size of aggregate in between 20 mm to 4.75 mm.The coarse
aggregate particle size distribution curve is presented in Fig. 3.1. The physical properties of both fine aggregate and recycled coarse aggregate are evaluated as per IS: 2386 (Part III)-1963 and given in Table 3.2.

Table 3.2: Properties of coarse aggregate and fine aggregate

Property	Coarse Aggregate	Fine Aggregate
Specific Gravity	2.72	2.65
Bulk Density(kg/L)	1.408	-
Loose Bulk Density(kg/L)	1.25	-
Water Absorption (%)	4.469	0.0651
Impact Value	26.910	-
Crushing Value	26.514	-
Fineness Modulus	3.38	2.84

Properties of Water

Tap water was used in this experiment. The properties are assumed to be same as that of normal water. Specific gravity is taken as 1.00.

Properties of Nano SiO_2

The average size of nano silica was found to be 236 nm from Particle Size Analyzer, there port of which has been presented in the Appendix. The properties of the material are shown in Table 3.3. Fig. 3. Shows the nano silica used in the experiment.

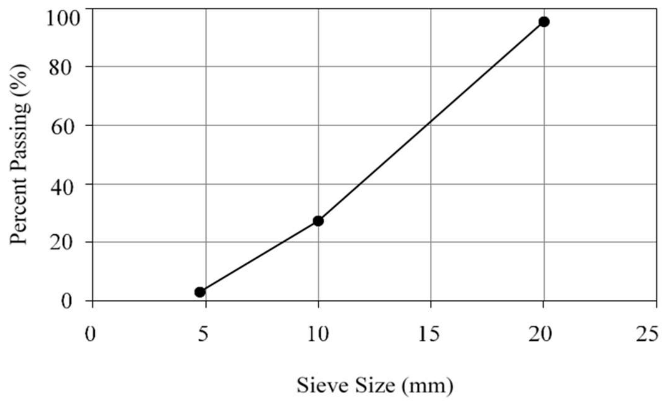

Fig.3.1: Size distribution curve for coarse aggregate

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Fig.3.2: Image of the Nano SiO_2 used

Table 3.3:Properties of Nano SiO_2

TESTITEM	STANDARD REQUIREMENTS	TEST RESULTS
SPECIFIC SURFACE AREA(m^2/g)	200±20	202
PH VALUE		
LOSS ON DRYING @ 105 DEG.C(5)	≤1.5	
LOSS ON IGNITION @ 1000DEG.C(%)	≤2.0	0.66
SIEVE RESIDUE(5)	≤0.04	
TAMPED DENSITY(g/L)	40–60	44
SiO2 CONTENT(%)	>99.8	
CARBON CONTENT(%)	≤0.15	
CHLORIDE CONTENT(%)	≤0.0202	
Al_2O_3	≤0.03	
TiO_2	≤0.02	
Fe_2O_3	≤0.003	0.001

METHODS

Mix Design

The mix design for M25 grade of concrete is described below in accordance with Indian Standard Code IS: 10262-1982.

TARGET STRENGTH FOR MIX PROPORTIONING:

Characteristic compressive strength at 28 days: f_{ck}= 25 MPa Assumed standard deviation (Table 1 of IS 10262:1982) : sd=4 MPa

Target average compressive strength at 28 days: $f_{target}=f_{ck}+1.65$ sd=31.6 MPa

I. SELECTION OF WATER-CEMENT RATIO:

From Table 5 of IS:456-2000,maximum water-cement ratio=0.50 To start with let us assume a water-cement ratio of 0.43

II. SELECTION OF WATER CONTENT:

Maximum water content per cubic metre of concrete (refer Table 2 of IS: 10262- 1982): W_{max} = 186L (for 50 mm slump).

Since, the slump was less than 50 mm, no adjustment was required.

III. CALCULATION OF CEMENT CONTENT:

Mass of water selected per cubic metre of concrete = 186 kg. Mass of cement per cubic metre of concrete=186/0.43=433kg.

Minimum cement content = 300 kg/m^3 (for moderate exposure condition, Table 5 of IS 456:2000)

Maximum cement content=450kg/m^3(Cl.8.2.4.2 of IS 456:2000) So, the selected cement content is alright.

IV. PROPORTION OF VOLUME OF COARSE AGGREGATE AND FINE AGGREGATE CONTENT:

Volume of coarse aggregate per unit volume of total aggregate (Table 3 of IS: 10262-1982) = 0.64 (This is corresponding to 20 mm size aggregate and Zone III fine aggregate for water-cement ratio of 0.50)

As the water-cement ratio is lowered by 0.05, the proportion of volume of coarse aggregate is increased by 0.01 (ref. Table 6 of IS: 10262-1982)

Corrected volume of coarse aggregate per unit volume of total aggregate=(0.64+0.014) = 0.654

Volume of fine aggregate per unit volume of total aggregate=1-0.654=0.346

V. MIX CALCULATIONS

i. Volume of concrete =1m^3
ii. Volume of cement=433/(3.01×1000)=0.144 m^3
iii. Volume of water =186/1000 =0.186 m3
iv. Volume of all aggregates =1-0.144-0.186 =0.67m3
v. Mass of coarse aggregate =0.654×0.67×2.72×1000= 1192 kg
vi. Mass of fine aggregate=0.346×0.67×2.65×1000=614kg

MIX PROPORTION:

For a batch of 6 cubes of 150mm side, the volume of concrete required

=$(0.15)^3$×6×1.2=0.024 m^3(taking into account 20 % extra for losses) Cement required = 0.024x433 = 10.4 kg
Fine aggregate required = 0.024x614 = 14.7 kg Coarse aggregate required =0.024x1192=28.6kg Water required = 0.024x186 = 4.5kg

EXPERIMENTAL RESULTS

UPV Test Results:

Fig 4.1-4.8 show UPV test results for specimen for 7 day and Fig 4.5-4.8 show UPV test results for specimen for 28 day.

Table 4.1: UPV Test for control specimen for 7 day

7-DAY TEST RESULT			
Sample No.	**Weight (kg)**	**Velocity (m/s)**	**Time (µs)**
1	8.10	4678	32.2
2	8.34	4702	31.9
3	8.36	4777	31.4

Table 4.2: UPV Test for specimen with nano-silica 0.3 % b.w.c for 7 day

7-DAY TEST RESULT			
SampleNo.	**Weight(kg)**	**Velocity(m/s)**	**Time (µs)**
1	8.18	4491	33.4
2	8.22	4491	33.4
3	8.24	4386	34.2

Table 4.3: UPV Test for specimen with nano-silica 0.6 % b.w.c for 7 day

7-DAY TEST RESULT			
SampleNo.	**Weight(kg)**	**Velocity(m/s)**	**Time (µs)**
1	8.26	4630	32.4
2	8.08	4630	32.4
3	7.98	4702	31.9

Table 4.4: UPV Test for specimen with nano-silica 1% b.w.c for 7 day

7-DAY TEST RESULT			
Sample No.	**Weight(kg)**	**Velocity(m/s)**	**Time (µs)**
1	8.24	4491	33.4
	8.14	4360	34.4
3	8.30	4559	32.9

Compressive Strength of control specimen for 7day

7-DAY TEST RESULT			
SampleNo.	**Weight(kg)**	**Load (tonne)**	**Compressive Strength (MPa)**
1	8.10	52	*
2	8.34	68	29.65
3	8.36	61	26.59
Mean			26.30

Table 4.10: Compressive Strength of specimen with nano-silica 0.3 % b.w.c for 7 day

7-DAY TEST RESULT			
SampleNo.	**Weight(kg)**	**Load (tonne)**	**Compressive Strength (MPa)**
1	8.18	67	29.21
2	8.22	71	30.95
3	8.24	52	22.67
Mean			27.61

Table 4.11: Compressive Strength of specimen with nano-silica 0.6 % b.w.c for 7 day

7-DAY TEST RESULT			
Sample No.	**Weight(kg)**	**Load (tonne)**	**Compressive Strength (MPa)**
1	8.26	66	28.77
2	8.08	72	31.39
3	7.98	76	33.14
Mean			31.1

CONCLUSION AND DISCUSSION

i. 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.

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

DISCUSSION

i. A study of relevant papers show that concrete blended with Nano SiO_2 sets quicker compared to normal concrete.Since,the mix design is carried out without the aid of supper- plasticizers, the mix dried up fast which affected the compaction of the mix using mechanical vibration. Lumps of the mix could be seen during the mixing of concrete.With increase in percentage of Nano SiO_2 the compaction gets tougher. This is the reason for degradation in its quality. It is advisable to use super plasticizers with nano silica.

ii. The Nano SiO_2 added to the mix filled up the pores in between the C-S-H gel, hence, making the microstructure more compact and uniform.

LIMITATIONS OF THE WORK

The current work has many limitations which are mentioned below:

i. The percentage of nano silica is restricted to 1 % due to workability issues which does not give a complete idea about the maximum amount of nano silica that can be added to get an increase in strength.

ii. Without the use of super plasticizers a proper compaction of the concrete was hindered.

iii. 7 day FESEM micrographs are unavailable which could have given a better idea about the early-age increase in strength.

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 micro structure at specific intervals through out 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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