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Preliminary Study on the Electrical Resistance and Capillary Absorption of Nano SiO_2 in High Performances Concrete

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Abstract: The principle of sustainable development and green building has penetrated the construction industry at an accelerating rate in recent years. In this regard, the idea of using by-product such as silica fume as partial replacement of cement in concrete, due to its great environment effect, became popular for producing infrastructures. On the other hand, colloidal nano silica, as a new material, is also known to promote concrete behavior. In the present work, different content of silica fume and nano silica as partial replacement of cement in the concrete mixture with 0.45 water-cement ratios were used simultaneously. It was concluded that 3% silica fume and 3% nano silica as partial replacements of cement, improved compressive strength and electrical resistance and also diminished capillary absorption of the concrete specimens seriously.
Keywords: Compressive Strength, Electrical Resistance, Capillary absorption.

Introduction

Nano technology has attracted considerable scientific interest due to the new potential uses of particles in the order of nanometer (10-9 m) scale. The nano scale-size particles can result in dramatically improved properties from conventional grain-size materials of the same chemical composition. The combination between fly ash and nano materials can tightly bond the hydration product which is regarded as an important factor for accelerating the pozzolanic reaction as it compensates for the increased early strength development. Although cement is a common building material, its main hydrate C–S–H gel is a natural nano-structured material, Hoon lim[2]. The mechanical and durability properties of concrete are mainly dependent on the gradually refining structure of hardened cement paste and the gradually improving paste–aggregate interface. Silica fume (silica fume) belongs to the category of highly pozzolanic materials because it consists essentially of silica in non-crystalline form with a high specific surface and thus exhibits great pozzolanic activity, Denise[3]. A new pozzolanic material Huili[5] the produced synthetically, in form of water emulsion of ultra-fine amorphous colloidal silica is available on the market and it appears to be potentially better than silica fume for the higher content of amorphous silica (> 99%) and the reduced size of its spherical particles (10-15 nm). Water permeability resistance and 28-days compressive strength of concrete were improved by using nano Para Addition of nano silica into high-strength concrete leads to an increase of both short-term strength and long-term strength In the present work, try have been done to assess the simultaneous effect of nano and silica fume on concrete performances.

2. Experimental details

2.1. Materials

2.1.1 Cement: Ordinary Portland cement of 53 grade confirming to IS 8112:1989 of locally available RAMCO cement which comprises good quality. The chemical configuration of cement was found using X-ray fluorescence analysis and has the following properties are given in table1.

Silica Fume powder (SF) and Nano-SiO_2 particles (NS). Their pertinent chemical and physical properties, as provided by the manufacturer, are given in Table 2. Scanning Electron Micrographs (SEM) images of silica fume and nano-SiO_2 are shown in Fig 1 and 2.

Table 1: Physical and chemical composition of ordinary Portland cement (OPC)

Description	Composition
Physical Properties	
Color	Grey
Specific gravity	3.15
Specific surface area (cm^2/g)	3540
Chemical Composition	
CaO (%)	62.8
SiO_2 (%)	20.3
Al_2O_3 (%)	5.4
Fe_2O_3 (%)	3.9
MgO (%)	2.7
Na_2O (%)	0.14
K_2O (%)	62.8

2.1.2 Fine aggregate: For fine aggregates, uncrushed locally available natural river sand of maximum size 2.36 mm with a fineness modulus of 3.35 and specific gravity of 2.65 using IS 2386(Part III):1963 was used.

2.1.3 Coarse aggregate: The size of the coarse aggregates used ranges between 10 mm to 12 mm of specific gravity 2.74 using IS 2386(Part III):1963.

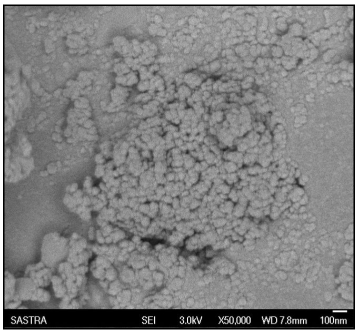

Fig.1 SEM image of nano-SiO_2

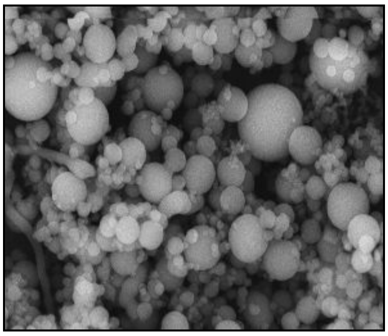

Fig.2 SEM image of silica fume

Table.2 Chemical composition and physical properties of Nano SiO_2 and Silica Fume materials

Items	Chemical compositions (%)		
	OPC	**Silica fume**	**Nano-SiO_2**
SiO_2	22.0	90-96	99.9
Al_2O_3	6.6	0.5-3	-
Fe_2O_3	2.8	0.2-0.8	-
CaO	60.1	0.98	-
MgO	3.3	0.5-15	-
SO_3	2.1	0.1-2.5	-
LOI	2.6	0.7-2.5	0.1
Physical properties			
Specific gravity	3.1	2.34	-
Avg. particle size	13μm	0.1μm	15nm
SSA(m^2/g)	0.38	20	60.08

2.2. Concrete mix design

High performances concrete ''HPC'' has been manufactured with and without nano particles in order to compare the well known performance of ''HPC'' without nano particles and with nano ones. High strength concrete with a cement content of 389 kg/m^3 was manufactured in all concrete mix. The water to cementitious materials ratio was equal 0.20 for all mixes. A proper dosage of super plasticizer is 20 kg/m3 for all mixes. The composition of high performance concrete with and without nano particles is shown in table 3.

Table 3: Composition of high performance concrete with and without nano materials

Name of specimens	%weight fraction of admixtures by cement					No. of specimens
	V_1	V_2	V_3	V_4	V_5	
AB	-	-	-	-	-	3
AR	-	-	-	-	-	3
AB	-	-	-	-	-	3
ACS	1	1.50	2	2.5	3	12
ARS	1	1.50	2	2.5	3	12
ABS	1	1.50	2	2.5	3	12
ARS	1	1.50	2	2.5	3	12
ABN	1	1.50	2	2.5	3	12
APN_1	1	1.50	2	2.5	3	12
ASN_1	1	1.50	2	2.5	3	12
ANN_1	1	1.50	2	2.5	3	12

2.3. Specimen preparation

Three types of specimens were made: 150 x150 x 150 mm cube, 150 x 300 mm cylinders, and 100 x 100 x 500 mm prismatic beams. After pouring the mixes into molds an electric vibrator was used to ensure good compaction. The specimens were then surface smoothed and covered with wet hessian. All specimens were remolded 1 day after casting. Thereafter, they were cured in standard water tank until testing at age. Cube specimens were used for determination of compressive strength development, electrical resistance development and capillary absorption. The casting specimens were remolded after 24 hours and then were cured in water. Testing ages were 3, 7, 28 and 91 days. Electrical resistance was measured via copper plates which were installed in top and bottom of the saturated concrete specimen at the ages of testing. Capillary absorption test was performed according to RILEM TC, CPC 11.2 (1982).

3. Experimental Results

3.1 Compressive Strength

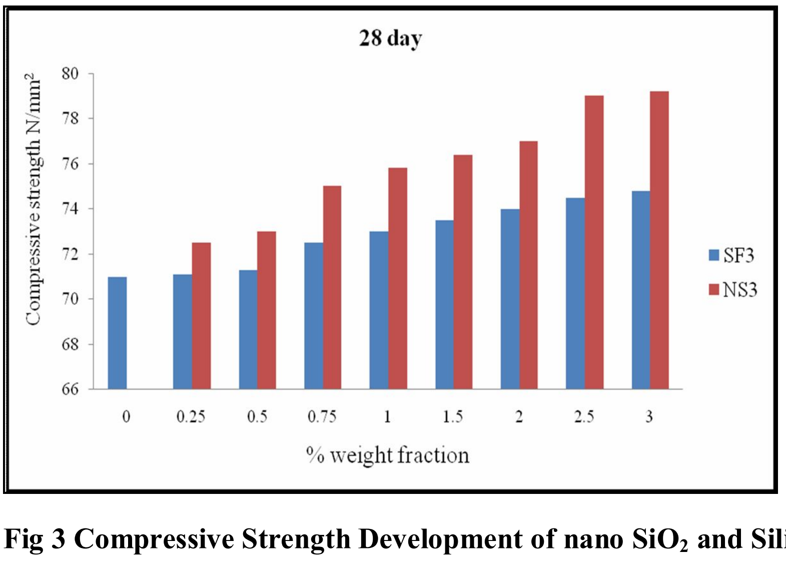

Fig 3 Compressive Strength Development of nano SiO_2 and Silica Fume

Fig. 3 shows the compressive strength development of concrete mixtures. The results show that increasing in nano silica content, 1.5% to 3% by weight, leads to an increase of compressive strength at all stages. The results also indicate that the specimens which contain nano and silica fume, due to the high pozzolanic activity have higher compressive strength than reference ones. However, large quantities of nano silica in the mixtures, due to agglomerate effect, don't lead to increase compressive strength. As it is shown the highest compressive strength at the age of 28 days is corresponding to SF and NS mixture.

3.2 Electrical resistivity

The electrical resistance development of the specimens which was measured at the age of 28 days is illustrated in Fig. 4. As it is shown, a considerable increase in electric resistance of later ages of 91 days, compare to the early age result is observed. This is, of course, due to hydration progress which occurred in the later ages. Similar to compressive strength results, the maximum electrical resistance, at the ages of 28 days, is attained in the mixture that contains 1% and 3% silica fume and nano silica, respectively. The resistivity of concrete is strongly dependent on the concrete quality and on the exposure conditions. In concrete material with high electrical resistivity the corrosion process will be slow compared to concrete with low resistivity in which the current can easily pass between anode and cathode.

3.3 Capillary absorption

The capillary absorption coefficient of the concrete mixtures is shown in Fig. 5. The results indicate that the lowest capillary absorption coefficient is belonging to the SF1-NS4 mixture. This result indicates that incorporation of nano SiO_2 and silica fume is an efficient way for decreasing of permeability.

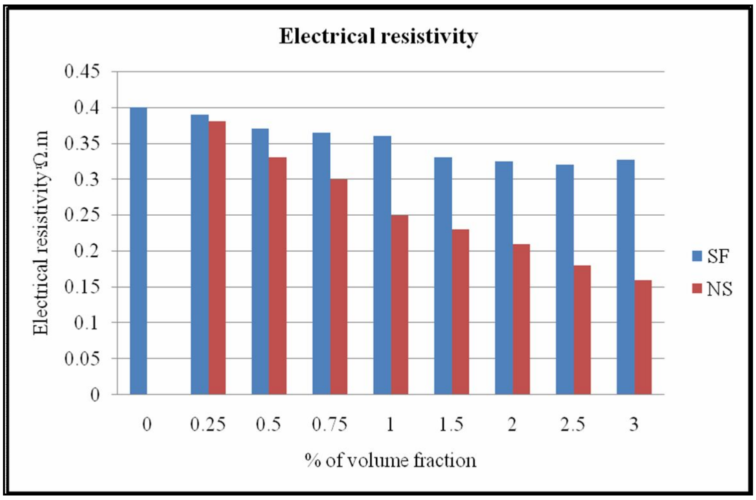

Fig 4 Electrical Resistance Development of nano Concrete

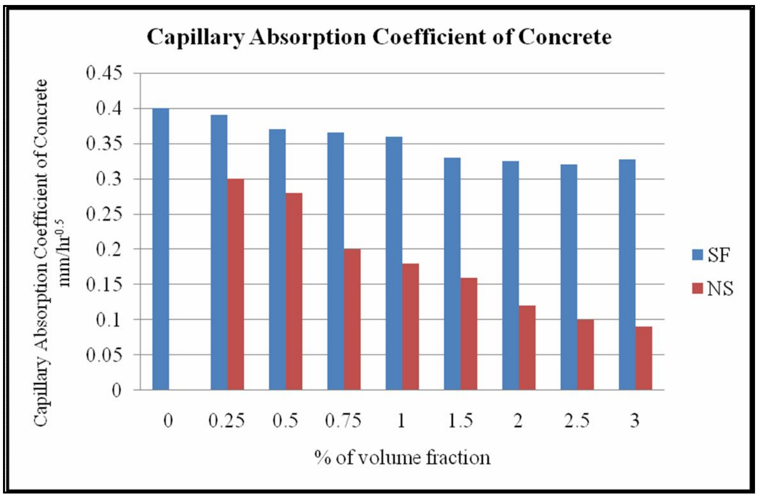

Fig 5 Capillary Absorption Coefficient of nano Concrete

Conclusions

The following conclusions can be drawn from the obtained experimental results:

a) The compressive strength of concrete had been improved by addition of nanoSiO_2 and Silica fume over the control conditions at all ages. But the nanoSiO_2 shows better results than that of Silica fume. The improvement of compressive strength of nanoSiO_2over Silica fume by around 43.2%.
b) A considerable increase in electric resistant of nano-silica fume specimens was observed compare to reference ones and the highest value was corresponding to the specimens which contain totally 20.9% nano and silica fume.
c) The capillary absorption rate decreased to a lowest level, when 1% silica fume and 3% nano silica were used in the mixtures. It seems that when nano silica was used at high value in the mixture a slight increase in the capillary coefficient was observed which is attributed to the agglomeration effect of nano silica in the mixtures.
d) Consequently, based on the present results, incorporation of colloidal nano silica and silica fume as partial replacements of cement have advantage effect on concrete performance.

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