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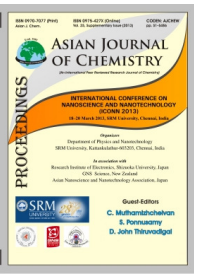

Property Improvement of Ordinary Portland Cement by Incorporating with Nanosilica†

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Nanotechnology has nowadays a pronounced impact on several areas of science and industry. Among several advantages, nano materials have been reported to introduce improvements in terms of system reliability, extend functionality beyond traditional applications and decrease energy consumption in structures. Nano materials can enable better utilization of natural resources and reaching required materials properties with minimal usage. Nano-cement and nano silica are among the recently used materials in this regard. In this paper the influence of nanosilica particles on the mechanical, physical and chemical properties has been studied through measurement of compressive strength, water absorption and the setting time measurements. The experimental results show that the mortar mixed with nano silica were better than that of plain cement mortar, as well as the water absorption results showed that the nano scale silica particles filled the cement paste pores and by reacting with calcium hydroxide crystals from calcium silicate hydration, decreased the size and amount of these crystals. Therefore the results indicate that nanoscale silica behaves not only as a filler to improve microstructure, but also as an activator to promote pozzolanic reaction.

Key Words: Nanosilica, Setting time, Compressive strength, Water absorption.

INTRODUCTION

Nanomaterials are poised for widespread use in the construction industry, where they can offer significant advantages for a variety of applications ranging from making more durable concrete to self cleaning windows. Various nano materials and nano composites are being considered for various uses in the construction and related infrastructure industries. In the modern age of concrete design, concrete researchers and developers are taking advantage of secondary cementitious materials to give concrete greater strengths. One of the newest technologies to break into the concrete design arena is the use of pozzolanic nano-particles in the concrete matrix. One such nano particle is nanosilica.

Nanosilica is typically a high effective pozzolanic material. It normally consists of very fine vitreous particles approximately 1000 times smaller than the average cement particles. It has proven to be an excellent admixture for cement to improve strength and durability and decrease permeability[1]. By using pozzolanic nano-particles, the development of the strength bearing crystals of cement paste can be increased/ controlled[2]. Microstructural analysis of concrete by different electronic microscope techniques (SEM, ESEM, TEM)[3] revealed that the microstructure of the nano silica concrete is more uniform and compact than for normal concrete. Ji *et al.*[4] demonstrated that nanosilica can react with $Ca(OH)_2$ crystals and reduce the size and amount of them, thus making the interfacial transition zone of aggregates and binding cement paste denser. The nanosilica particles fill the voids of the CSH-gel structure and act as nucleus to tightly bond with CSH-gel particles. This means that nanosilica application reduces the calcium leaching rate of cement pastes and therefore increasing their durability.

The present work investigates the pozzolanic activity of nanosilica by the way of measuring setting time, compressive strength and water absorption, in order to verify the pozzolanic reaction of nanosilica admixtured cement mortar.

EXPERIMENTAL

The cementitious materials used in this test were ordinary portland cement and nanosilica. Their chemical compositions are given in Table-1. The commercial Portland cement (OPC) was used and nanosilica was purchased from micromaterial private limited, Bangalore, India.

Water consistency measurement: The water consistency was determined by Vicat apparatus (IS:4031 part 4, 1988) and

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was found to be 27 % for ordinary portland cement and 40 % for ordinary portland cement + 5 wt % nanosilica blended cement. So water/solid ratio was kept 0.4 in both cases.

TABLE-1
CHEMICAL COMPOSITION ORDINARY PORTLAND CEMENT (OPC) AND NANOSILICA

Oxides	OPC	Nanosilica
SiO_2	21.70	90.36
Al_2O_3	5.40	0.26
Fe_2O_3	3.40	0.23
CaO	63.32	0.22
MgO	0.12	0.21
K_2O	-	0.11
Na_2O	-	0.23
TiO_2	-	0.21
MnO	-	0.26
P_2O_5	-	0.26
SO_3	2.10	0.23
Insoluble residue	1.08	0.23
Loss on ignition	0.79	0.21

Determination of setting time: Initial setting time and final setting time has been measured on nanosilica admixtured cement (0.5 %) in a water to cement ratio of 0.4 treated with groundwater. Setting time of admixtured cement paste was measured using a Vicat needle apparatus using standard procedure[5] and the results are shown in Table-2.

Determination of compressive strength: The compressive strength of ordinary portland cement and nanosilica admixtured cement mortar (0 %, 5 %) were determined using compression testing machine. Compressive strength tests were carried out on 150-mm cube specimens, according to IS 4031 part 3, 1988. The specimens were cured with different ages (3, 7, 28 days) and the average strength of three specimens were noted and the results are shown in Table-2.

Determination of water absorption: Porosity of the mortar cubes made with Portland cement and nanosilica admixtured cement treated with GW was determined at 1 day, 1week and 4 weeks by oven drying method[6] using the relation $((M_s-M_o)/(M_s-M_h)) \times 100$. The water absorption was obtained using the formula: $(100 \times (M_t-M_o)/M_o$. Where M_t is the mass of the wet sample when in contact with water for a period of time t, M_s is the mass of the saturated test sample, M_o is the mass of the dried test sample, M_h is the hydrostatic weight of the saturated test sample. The computed results are shown in Table-2.

RESULTS AND DISCUSSION

Setting time measurements: The initial and final setting time of the Portland cement and nanosilica admixtured cement paste with ground water is shown in Table-2. The setting time of the 5 % nanosilica admixtured cement paste is shorter than Portland cement paste. The reduction of the setting times of the nanosilica cement paste may be related to the finer particle size and higher surface area compared to ordinary cement paste which reduced the dormant period and increased cement hydration[7].

Compressive strength measurements: The experimental results from compressive strength tests are summarized in Table-2. It can be seen that, when nano particles in a small amounts are added, compressive strength at 3 days can be enhanced. This resulted the increasing of the bound strength of cement paste-aggregate interface by means of the filing effect of nano silica particles. An interesting observation is that at 7 days result of increasing pozzolanic reaction with the $Ca(OH)_2$ generated during the ordinary portland cement hydration[8]. At 28 days of compressive strength of nanosilica admixtured cement was increased when compared to Portland cement. This may be attributed to strongest bond between the hardened paste and the aggregates.

Porosity measurements: The results of porosity *vs*. hydration times for all hydrated samples are shown in Table-2. In the ground water treated samples the compressive strength of the mortar increases with 5 % nanosilica and consequently decrease in percentage of porosity are observed. This is due to high reactivity, additional C-S-H gel formed as a result of the pozzolanic reaction will have the effect of filling pores, thus reducing total porosity and increasing pore refinement[9].

Water absorption measurements: The water absorption results are shown in Table-2. The addition of nano particles is much more favourable to the water absorption resistance of mortar than the reference ordinary portland cement mixture. The mechanism of nano particles effects on water absorption can be represent as follows. Supposed that nano particles are uniformly dispersed, the distance between nano particles can be specified, the hydrate products diffuse and envelop nano particles as kernel[10]. The nano particles react with $Ca(OH)_2$ crystals as a pozollanic material. This makes the cement matrix more homogeneous and compact, also reduced height and blocked capillary pipes, thus the abrasion and capillarity of water absorption resistance and strength are improved apparently.

Conclusion

• From the experiments performed, it was validated that as the silica decreases in size and increases in size distribution, a number of properties begin to improve. Because the silica is on the nano scale more effective, due to exposed surface area, in reacting pozzolanically.

• Compressive strength of the mortar increases with adding the nano-silica. These results indicate that the pozzolanic activity of nano-silica is greater.

• Nano-silica consumes calcium hydroxide crystals, reduces the size of the crystals at the interface zone and transmute the calcium hydroxide feeble crystals to the C-S-H

TABLE-2
SETTING TIME, COMPRESSIVE STRENGTH, POROSITY AND WATER ABSORPTION OF NANOSILICA ADMIXTURED CEMENT TREATED WITH GROUND WATER

NS %	Setting time hr. min		Compressive strength (MPa) 3 days	7 days	28 days	Porosity (%) 3 days	7 days	28 days	Water absorption (%) 3 days	7 days	28 days
	initial	final									
0	5.00	6.45	10.5	32.2	47.8	15.2	14.5	10.6	8.2	7.4	7.0
5	4.35	6.15	19.0	42.2	57.0	14.0	13.2	8.5	7.8	7.0	6.2

crystals and improves the interface zone and cement paste structures.

• The addition of nano particles is much more favourable to the water absorption resistance of mortar than the reference mixture.

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