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Influence of Nano-Silica Particles on Mechanical Properties and Permeability of Concrete

Mostafa.Khanzadi [1] Mohsen.Tadayon [2] Hamed.Sepehri [3] and Mohammad.Sepehri [4]

[1]Assistant professor, Department of Civil Engineering, Science & Technology University of Iran, Tehran, mailing address: Department of civil engineering of science and technology university of Iran, narmak st, Tehran, Iran, e-mail: <Khanzadi@iust.ac.com>
[2]Assistant professor, Department of Civil Engineering, Buali Sina University, Hamadan, Iran, Mailing address: Department of civil engineering of Buali sina university, daneshgahblv, Hamadan, Iran, e-mail: <Tadayonmoh@yahoo.com>
[3]M.S. Student, Dept of civil Engineering. Science & Technology University of Iran, Tehran, Mailing address: Unit 10, no 31, shahid kashani alley, seraj st, farjam st, Tehran, Iran, e-mail: <Haz223@yahoo.com>
[4]B.S. Student , Dept of civil Engineering Islamic Azad university of Kermanshah, Iran, Mailing address: Unit 6, no 16, khanesazi complex, motakhasesin area, Kermanshaht, Iran, e-mail: <Msk1272@yahoo.com>

ABSTRACT

Recently, nano particles have been gaining increasing attention and have been applied in many fields to fabricate new materials with novel functions due to their unique physical and chemical properties. In this paper the influence of nano silica particles on the mechanical properties and durability of concrete has been studied through measurement of compressive and tensile strength, water absorption, and the depth of chloride penetration**.** The experimental results show that the mechanical properties measured, and the durability of the concrete mixed with the nano particles were better than that of a plain concrete, also the SEM study of the microstructures showed that the nano 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 nano scale silica behaves not only as a filler to improve microstructure, but also as an activator to promote pozzolanic reaction.

INTRODUTION

It has been well recognized that the use of pozzolanic materials such as silica fume and fly ash is necessary for producing high performance concrete (HPC), because of significant improvements attained on the interfacial zone of cement paste-aggregate [Aitcin PC 1983, Malhotra M and Ramachandran R 1987]. In recent years, there has been a growing interest in the use of nano silica (NS) as a mineral admixture for similar purposes [Byung-Wan Jo 2007, Hui.Li 2004, R.S.Chen 2002, Ye.Qing 2007]. The durability and mechanical properties of HPC are mainly dependent on gradually refining the structure of hardened cement paste and gradually improving paste-aggregate interface by incorporating additions and admixtures [Ye.Qing 2007]. Nano silica particles can react with calcium hydroxide crystals, which are arrayed in the interfacial transition zone (ITZ) between hardened cement paste and aggregates, and produce C-S-H gel [R.S.Chen 2002]. Tao Ji reported that nano silica can improve water permeability of concrete [Tao Ji 2005]. Hui Li examined cement mortars with nano-Sio_2 and nano-FE_2O_3 to study their super mechanical and smart (temperature and strain sensing) potentials [Hui.Li, Hui and Gang.Xiao 2007]. Byung-Wan investigated cement mortar with nano-silica [Byung-Wan Jo and Chang-Hyun Ki 2007].

Nano-silica can behave as nucleuse to tightly bond with cement hydrates [Wang.B and Wang .L 2008]. A stable gel structure can be formed and the mechanical properties of hardened cement paste can be improved when a smaller amount of nano silica is added [R.S.Chen 2002].

However, up to now, there are few published reports on the durability of nano silica concrete. SEM tests were performed to investigate the permeability of concrete with nano silica particles. The research shows that nano silica can improve the micro structure of the ITZ and durability of concrete.

EXPERIMENTAL

Materials And Mixture Properties

Cement :The cement used is Portland cement (PI 1.425) and the properties shown in Table1.

Table 1: Physical and Chemical Properties of Cement

Compounds	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	C_3S	C_2S	C_3A	C_4AF	Fines (cm2/gr)	Vicat test (min)		Standard cube test (MPa) at 3, 7 and 28 Days		
												Init.	Final	3	7	28
Value(%)	21.38	4.45	3.51	63.06	3.20	1.80	52.5	21.5	6.4	10.7	3298	200	260	178	354	461

Aggregation: in this research round corner sand with density of 2550 kg/m³ and gravel with particle size of 12.5 mm and density of 2630 kg/m³ were used that both of them were from river type. It should be mentioned that aggregations were granulated based on ASTMC 136-96 standard (Annual Book of ASTM Standards, Vol 04.02).

Superplastisizer: The superplastisizer used is Glenium 51p (one kind of polycarboxilat).

Water: The water was used in this experiment with PH =7.5.

Nano-silica: The nano-silica used in this research is from water soluble type with 15% suspension produced by Sweden that its chemical specifications are given in Table 2.

Table 2- Chemical Specifications of Consumed Nano-Silica

Diameter of particles nm	Density (g/cm^3)	Purity percentage
5	1.1	99.9

The water-to-binder (the sum of the cement and nano particles) ratio used for all mixtures is 0.45 and the mixture's slump was 30±5 mm. The mixture proportions per cubic meter of concrete are given in Table 3. Herein, OPC denotes plain concrete and NANO denotes the mixture containing nano silica.

Table 3: Mix Proportions

Name of mixture	cement (^{3}	water ^{3}	sand ^{3}	gravel (^{3}	Nano-silica ^{3}	superplastisaizer ^{3}
OPC	350	187	1068	735	-	-
NANO	345	148	1053	724	5.25	3.92

Specimen Fabrication

First, the coarse aggregates, which were saturated surface dry, were placed in the mixer. The binder and fine aggregates were added and mixing resumed for 1 min, then gently adding the 75% of mixing water and mixed for 2.5 min, the 25% mixing water which was premixed with the superplasticizer and the nano-silica was added and mixing for 1.5 min. Finally, the fresh concrete is poured into oiled molds and after pouring an external vibrator is used to facilitate compaction and decrease the amount of air bubbles. The specimens are demolded at 24h and then cured in a standard watering place at temperature of 20±3 C.

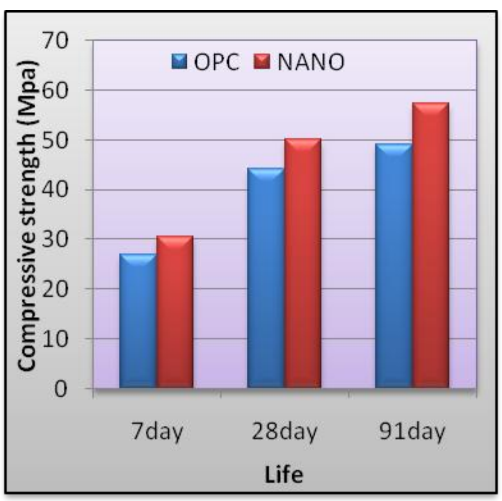
Testing Methods

The compressive and tensile strength tests were performed in accordance with BS EN1881, 108, 110 and ENBSEN 12390-6 respectively, and cubic tests of 100 millimeters for compressive strength and cylindrical test of 100×200 millimeters for tensile strength were used. Water absorption was tested by taking patterns of BS EN 12390-Part 8 command similar to old BS 1881 as a weight percentage gained by use of average calculation of three cubic tests of 100 millimeters. The test of capillarity of water absorption was done based on instructions of TC 14-CPC, RILEM CPC 11.2 and average of three cubic tests of 100 millimeters. For determination of distribution coefficient of chloride ion to depth of 20 millimeters, concrete powder was prepared from every 5 millimeter and from 20 to 30 millimeter depth also a sample of concrete's powder taking was done. Therefore, the gained powders related to depths (0-5), (5-10), (10-15), (15-20) and (20-30) millimeter. The powders provided from each depth were mixed with each other in five aspects of three tests and were used in test of density dissolved chloride ion concentration in water. For determination of chloride ion existing in each depth the approach of ASTM C 1218 which is indicative of density of chloride ion solved in water was used.

TEST RESULT AND DISCUSSIONS

Compressive And Splitting Tensile Strengths

The figures 1 and 2 shows the compressive and split strength of all specimens at 7^{th} , 28^{th} and 91^{th}days. It can be seen that, when nano particles in a small amounts are added, both the compressive and splitting strengths of concrete can be enhanced. This result is a result of increasing the bound strength of cement paste-aggregate interface by means of the filing effect of nano silica particles.



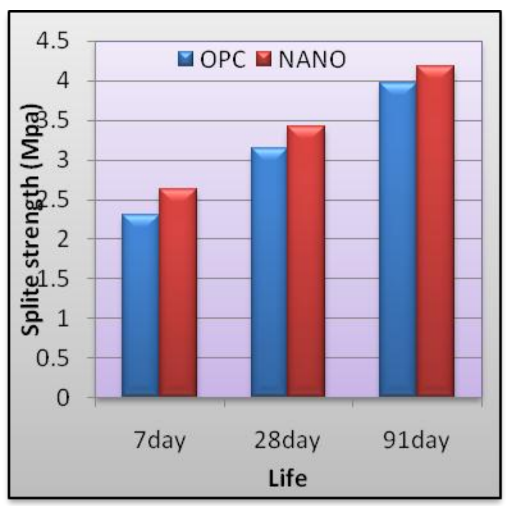
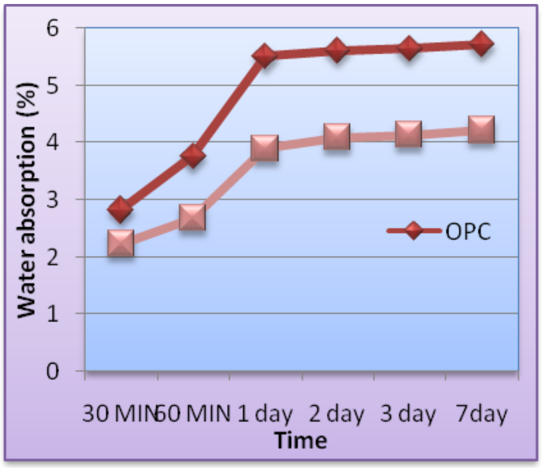


Figure1: Compressive Strength **Figure2: Split Strength**

Water absorption

The water absorption and capillary absorption results shows in figures 3 and 4. The addition of nano particles is much more favorable to the water absorption resistance of concrete than the reference mixture.



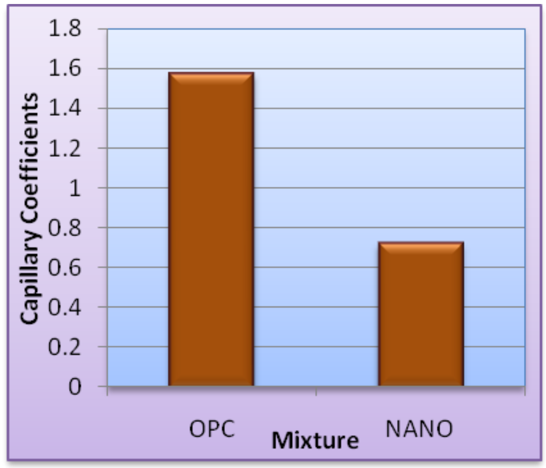


Figure 3: Absorption Percents **Figure 4: Capillary Coefficients**

The mechanism of nano particles effects on water absorption and capillarity of water absorption resistance of concrete 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. 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. To verify the mechanism predicated by compressive and tensile strength test and permeability test, SEM examination were performed.

Distribution Coefficient of Chloride Ion

Table 4- distribution coefficients, calculated Cs and correlation coefficients of regression lines from chloride profile data (calculations are done by use of chloride profile proportioned to concrete's weight)

TABLE 4: Diffusion Coefficient of Chloride Ion

mixture	OPC	NANO
D mm^2 /year	159.87	157.9
Calculating C_S	4.99	4.19
R^2	0.976	0.942

D: distribution coefficient of chloride ion,
R^2: correlation coefficients of liner regression

by adding nano-silica, hydration products increase and crystals decrease, also filling effect of fine granulation and more concentration of cement paste structure cause confinement of porous. Therefore, few void spaces are provided for gathering and as a result permeability of concrete is reduced, thus the distribution coefficient of chloride ion is decrease.

Scanning electron microscope

Figures 5(a,b) are SEM micrographs of reference concrete and concrete with nano-silica respectively.

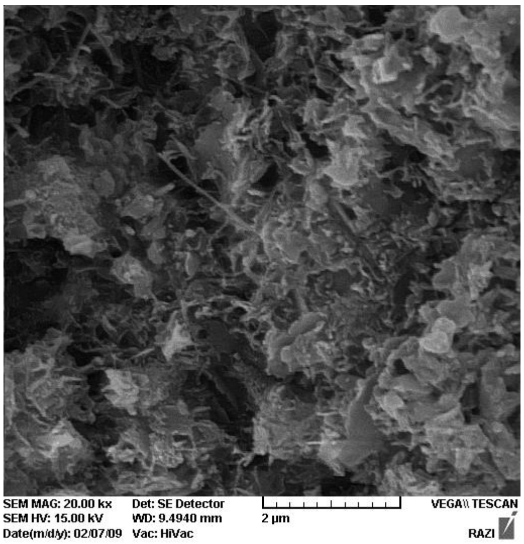


Figure 5(a): SEM of OPC Concrete

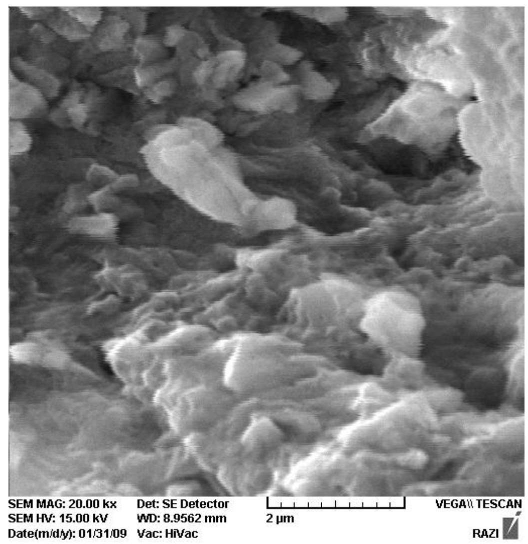


Figure 5(b): SEM of Nano-Silica Concrete

The SEM shows that the microstructure of the nano-silica concrete is more denser and homogeneous than of the plain concrete, through the pozollanic reaction and filer function of silica particles.

Conclusion

1 Compressive and tensile strength of the concrete increases with adding the nano-silica, especially at early ages. However the early strength of the concrete decreases slightly with adding the silica fume, but increases at later ages. These results indicate that the pozzolanic activity of nano-silica is greater than that of silica fume.

2 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 crystals, and improves the interface zone and cement paste structures.

3 The water absorption, capillary absorption and distribution of chloride ion tests indicate that the nano-silica concrete has better permeability resistance than the normal concretes, Due to the microstructure of the nano silica concrete is more uniform and denser than that of reference concrete as shown in The SEM test.

REFERENCES

Aitcin PC, 1983. Condensed silica fume. *Quebec, Canada, Editions de L'Universite de Sher brooke, Sherbrooke.*

Annual Book of ASTM Standards, Vol 04.02, C 136-96 Standard : Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.

Byung-Wan Jo, Chang-Hyun Kim, 2007. Characteristics of Cement mortar with nano-SiO2 Particles. *Construction and Building Materials* **21** 1351-1355.

Hui.Li, Hui-gang.Xiao, Jie.Yuan, 2004. Microstructure of cement mortar with nano-Particles. *Composites*, **part B** 185-189.

Malhotra M, Ramachandran R, Feldman R, Aitcin PC, 1987. Condensed silica fume in concrete. *Boca Raton, Florida*: CRC Press.

R.S.Chen, Q.Ye, 2002. Research on Comparison of Properties of Harddened Cement Paste Between Nano sio2 and Silica Fume add. *Concrete research* **1**, 7-10.

Q.Ye, 2001. research on the comparison of pozzolanic activity between nano-sio2 and silica fume. *Cement and Concrete research* **3,** 128-136.

Tao Ji, 2005. Preliminary Study on Water Permeability and Microstructure of Concrete Incorporating Nano- sio2. *Cement and Concrete Research* **35**, 1943-194.

Wang .B, Wang .L, 2008. Freezing Resistance of HPC with nano-sio2. *Jurnal of Wuhan University Technology –Mater. Sci. Ed. Feb.*

Ye.Qing, Zhang.Zenan, Kong.Deyu, 2007. Influence of Nano-SiO2 Addition on Properties of Hardened Cement Paste as Compared With Silica Fume. *Construction and Building Materials* **21,** 539-545.