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Influence of Nano-SiO_2 and Microsilica on Concrete Performance

M. Nili[*a], A. Ehsani [a], and K. Shabani [b]

[a] *Civil Eng., Dept., Bu-Ali Sina University, Hamedan, I.R. Iran*
[b] *Eng., Research Institute of Jahad-Agriculture Ministry, Tehran, I.R. Iran*
[*a] *corresponding author,< nili36@yahoo.co.uk>,< ehsani.ahmad@gmail.com>*

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 microsilica as partial replacement of cement in concrete, due to its great environment effect, became popular for producing infrastructures. On the other hand, colloidal nanosilica, as a new material, is also known to promote concrete behavior. In the present work, different content of microsilica and colloidal nanosilica as partial replacement of cement in the concrete mixture with 0.45 water-cement ratios were used simultaneously. It was concluded that 6% microsilica and 1.5% nanosilica as partial replacements of cement, improved compressive strength and electrical resistance and also diminished capillary absorption of the concrete specimens seriously.

INTRODUCTION

In this new century, the technology of nano-structured material is developing at an astonishing speed and will be applied extensively with many materials. Although cement is a common building material, its main hydrate C–S–H gel is a natural nano-structured material [Qing, Y., Zenan, Z., Deyu, K., Rongshen, C., 2007]. 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. Microsilica (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 [Qing, Y., Zenan, Z., Deyu, K., Rongshen, C., 2007; Mitchell DRG, Hinczak I, Day RA., 1998]. A new pozzolanic material [Skarp, U., and Sarkar, S.L, 2000. Collepardi, M., Ogoumah Olagot, J.J., , Skarp, U. and Troli, R ,2002 Collepardi, M., Collepardi, S., Skarp, U., Troli, R, 2002] produced synthetically, in form of water emulsion of ultra-fine amorphous colloidal silica (UFACS), 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 (1-50 nm). Water permeability resistance and 28-days compressive strength of concrete were improved by using nanosilica [Ji, T., 2005]. Addition of nanosilica into high-strength concrete leads to an increase of both short-term strength and long-term strength [Li, G., 2004]. In the present work, try have been done to assess the simultaneous effect of nano and micro silica on concrete performances.

MATERIALS AND TESTING PROGRAM

Crushed stone, with 19 mm maximum nominal size, in two ranges of 5-10 and 10-19 with relative density at saturated surface dry of 2.61 were used. Fineness modulus of sand and relative density were 3.24 and of 2.56 respectively. Water absorption of fine and coarse aggregate is 3.09% and 2%, respectively. Porland cement type 2, with a specific gravity of 3.11 and 3750 cm^2/gr surface area was used. A commercial carboxylic type plasticizer, (Gelenium 110M, BASF Co.), was used to adjust workability of the fresh concrete. Silica fume, made by Semnan Ferro Alley factory (IFC Co.), was used at 0%, 3%, 4.5%, 6% and 7.5% (by weight) as partial replacement of cement. Colloidal nanosilica, made by Akzo Nobel Chemicals GmbH (Cembinder® 8) was also used at 0%, 1.5%, 3% and 4.5% (by weight) as partial replacement of cement. The characteristics of cementitious materials are given in Table 1. Mix proportions of the concrete mixtures and results of fresh concrete slump tests are given in Table 2. Water-cementitious material (w/cm) ratio of all mixtures is constant and equal to 0.45. The colloidal nanosilica was mixed with Superplasticizer and half of the mixing water. A pan mixer was used and the mixing procedures are as follows. At the beginning, sand, cement, half of the mixing water and half of the admixture content were mixed for 1 minute. Then, the remaining water and admixture and also coarse aggregate were added into the mixture and mixed for 2 minutes. Cube specimens (100×100×100 mm) 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).

Table 1. Chemical Composition and Physical Properties of Cementitious Material

Material	Chemical composition (%) and Physical properties
Cement	Al_2O_3, 4.75; SiO_2, 26.58; P_2O_3, 0.26; SO_3, 7.74; K_2O, 0.76; CaO, 55.75; TiO_2, 0.24; Cr_2O_3, 335ppm; MnO, 0.13; FeO, 3.83; SrO, 665ppm; As_2O_3<144 ppm; CuO, 185ppm;
Microsilica	SiO_2, 85-95; C, 0.6-1.5; Fe_2O_3, 0.4-2; CaO, 2-2.3; Al_2O_3, 0.5-1.7; MgO, 0.1-0.9;
Colloidal Nanosilica	Average primary particle size: 50-60 nm; Specific surface area (BET): 80 m^2/g; Solid content (SiO_2-content): 50 wt %; density: 1.4 g/cm^3; Ph: 9.5; Viscosity: <15 cPS;

Table 2. Mix Proportions of the Concrete Mixtures

NO	Mixture	MicroSilica wt.%	Nanosilica wt.%	cement kg/m^3	water kg/m^3	Fine Agg. kg/m^3	Coarse Agg. kg/m^3	SF (Micro Silica) kg/m^3	NS (Colloidal Silica) kg/m^3	Super Plasticizer kg/m^3	Slump cm
1	Ref	0	0	400	180	811	915	0	0	1.40	7.5
2	SF0-NS1.5	0	1.5	394	174	811	915	0	12	1.68	7.5
3	SF0-NS3	0	3	388	168	811	915	0	24	2.32	7
4	SF0-NS4.5	0	4.5	382	162	811	915	0	36	3.00	7.5
5	SF3-NS1.5	3	1.5	382	174	811	915	12	12	2.44	7
6	SF3-NS3	3	3	376	168	811	915	12	24	2.40	7
7	SF4.5-NS1.5	4.5	1.5	376	174	811	915	18	12	2.60	8.5
8	SF4.5-NS3	4.5	3	370	168	811	915	18	24	2.80	8
9	SF6-NS1.5	6	1.5	370	174	811	915	24	12	2.20	7.5
10	SF7.5-NS0	7.5	0	370	180	811	915	30	0	2.08	8.5

EXPERIMENTAL RESULTS

Compressive strength

Fig. 1 shows the compressive strength development of concrete mixtures. The results show that increasing in nanosilica content ,1.5% to 4.5% by weight, leads to an increase of compressive strength at all stages. The results also indicate that the specimens which contain both nano and micro silica, due to the high pozzolanic activity, have higher compressive strength than reference ones. However, large quantities of nanosilica 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 SF6, NS1.5 mixture.

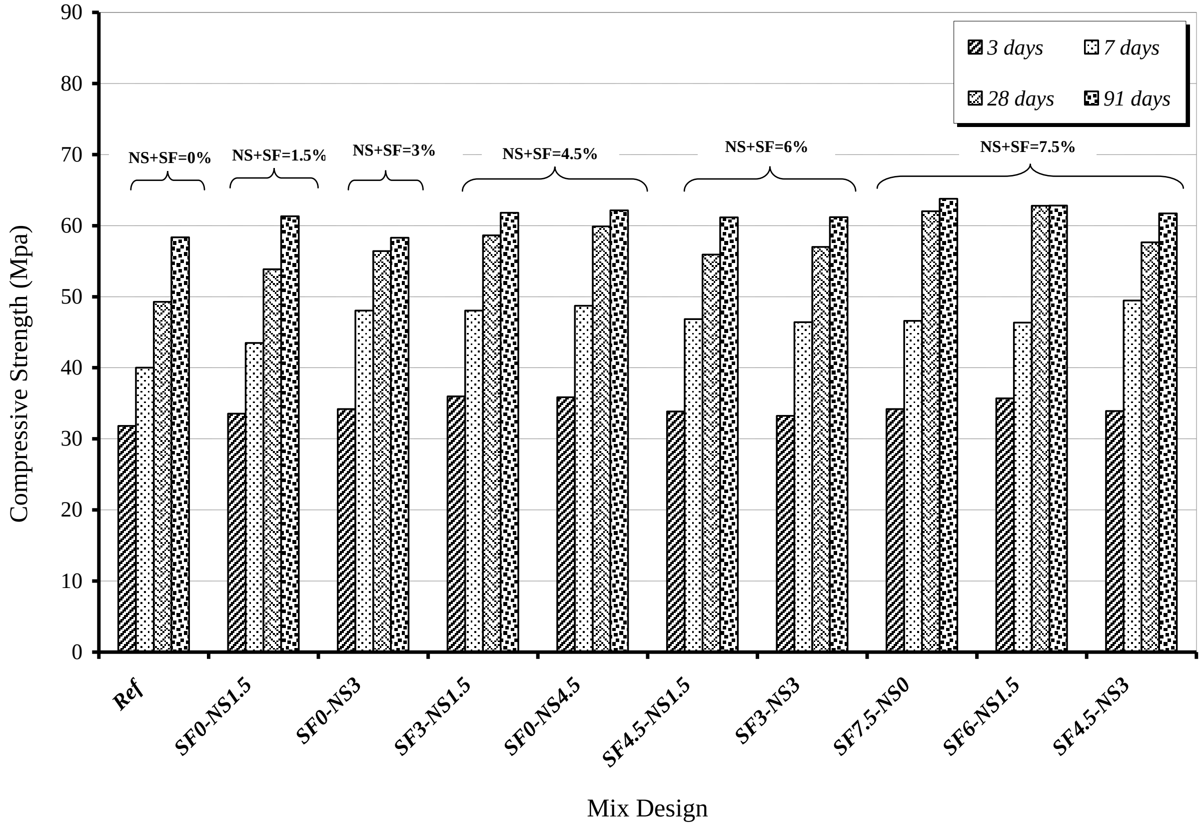

Fig 1. Compressive Strength Development of Concrete Mixtures

Electrical resistivity

The electrical resistance development of the specimens which was measured at the ages of 3, 7, 28 and 91 days is illustrated in Fig. 2. 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 6% and 1.5% microsilica and nanosilica, 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 areas [Song, H. W., Saraswathy, V., 2007].

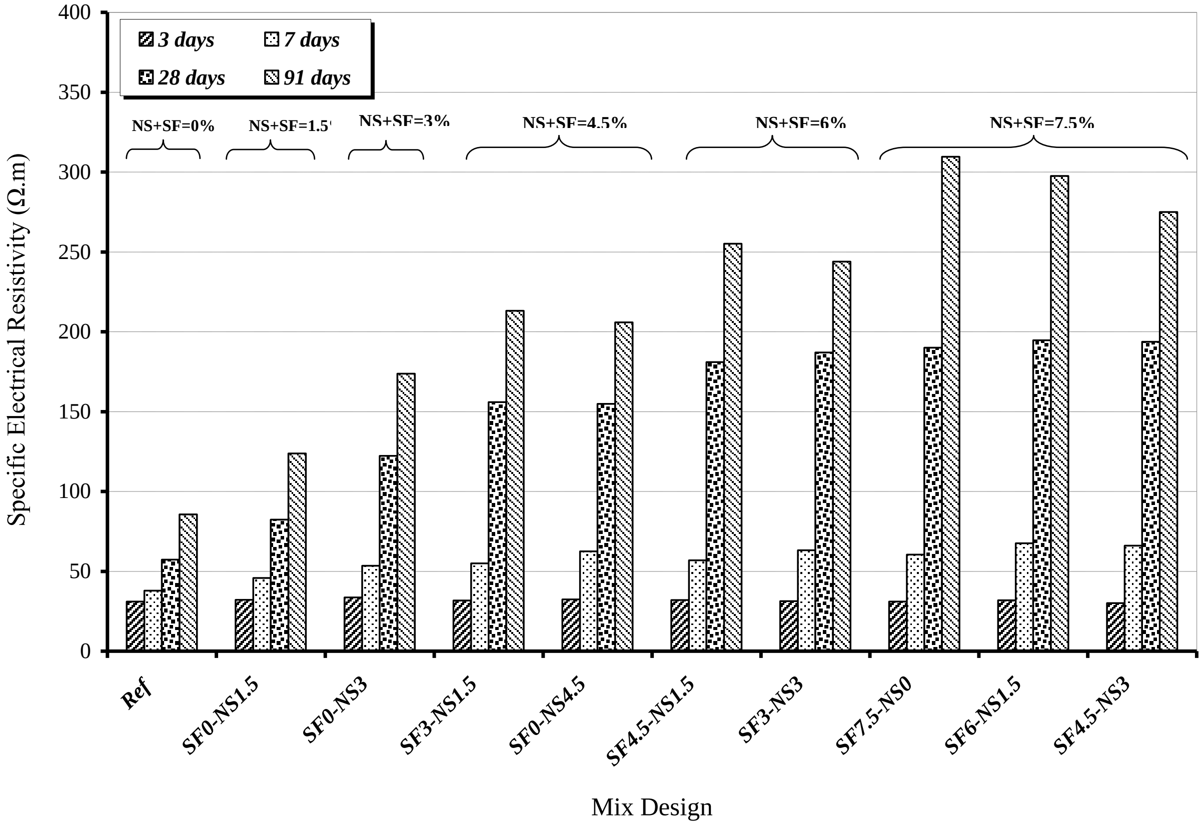

Fig 2. Electrical Resistance Development of Concrete Mixtures

Capillary absorption

The capillary absorption coefficient of the concrete mixtures is shown in Fig. 3. The results indicate that the lowest capillary absorption coefficient is belonging to the SF3-NS1.5 mixture. This result indicates that incorporation of nano and micro silica is an efficient way for decreasing of permeability.

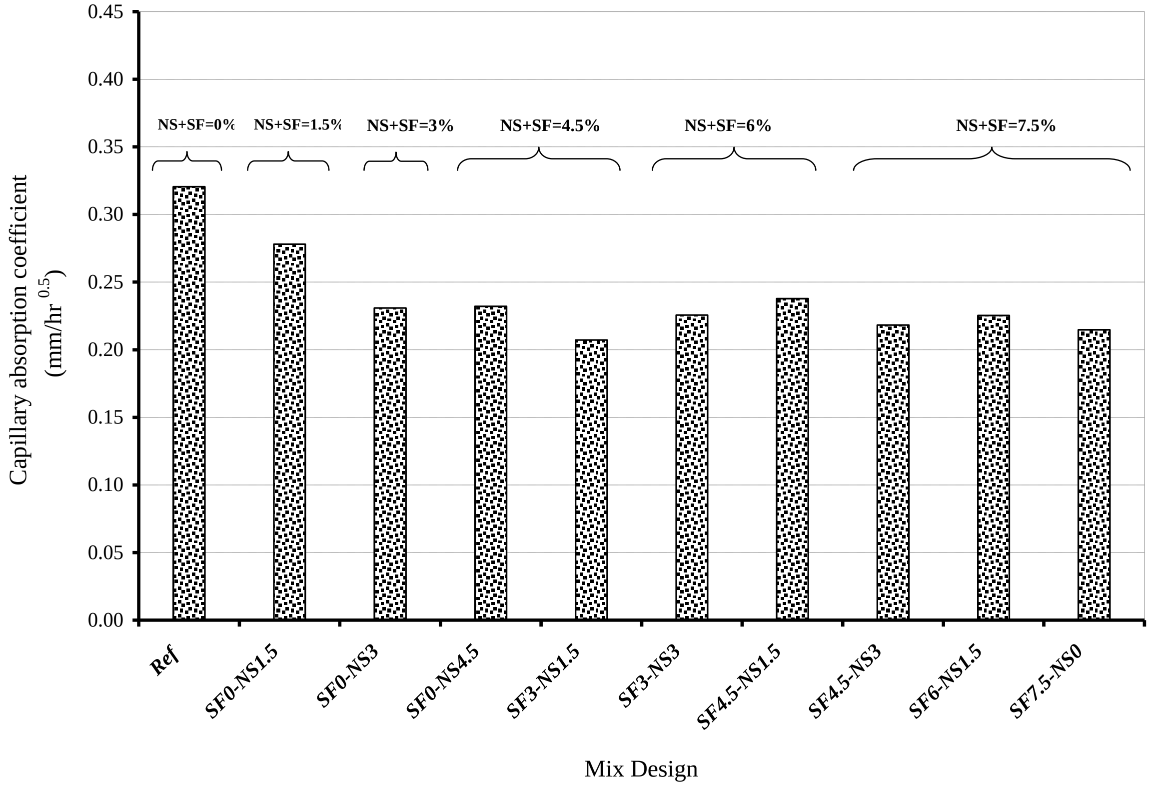

Fig 3. Capillary Absorption Coefficient of Concrete Mixtures

CONCLUSIONS

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

- The highest compressive strength at the ages of 7 and 28 days was attained when the mixtures contain 6% microsilica and 1.5% nanosilica.
- A considerable increase in electric resistant of nano-micro silica specimens was observed compare to reference ones and the highest value was corresponding to the specimens which contain totally 7.5% nano and micro silica.
- The capillary absorption rate decreased to a lowest level, when 3% microsilica and 1.5% nano silica were used in the mixtures. It seems that when nanosilica 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 nanosilica in the mixtures.
- Consequently, based on the present results, incorporation of colloidal nanosilica and microsilica as partial replacements of cement have advantage effect on concrete performance.

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