International Journal of Architectural, Civil and Construction Sciences
ISSN: 2415-1734
Vol:9, No:3, 2015

Preparation and Physical Assessment of Portland Cement Base Composites Containing Nano Particles

Amir Mahmoudi

***Abstract*—**In this research the effects of adding silica and alumina nanoparticles on flow ability and compressive strength of cementitious composites based on Portland cement were investigated. In the first stage, the rheological behavior of different samples containing nanosilica, nanoalumina and polypropylene, polyvinyl alcohol and polyethylene fibers were evaluated. With increasing of nanoparticles in fresh samples, the slump flow diameter reduced. Fibers reduced the flow ability of the samples and viscosity increased. With increasing of the micro silica particles to cement ratio from 2/1 to 2/2, the slump flow diameter increased. By adding silica and alumina nanoparticles up to 3% and 2% respectively, the compressive strength increased and after decreased. Samples containing silica nanoparticles and fibers had the highest compressive strength.

***Keywords*—**Portland cement, Composite, Nanoparticles, Compressive Strength.

I. Introduction

PORTLAND cement and cementitious based composites are used in various industrial and biomedical applications [1], [2]. Many researches have been done to improve the properties and formability of theses composites by adding fibers and nanoparticles [2], [3]. Nanoparticles increase hydration of cement due to high reactivity, reduce the porosity between grains and improve the strength of cementitious composites [4], [5]. Hydration of Portland cement results in the deposition of calcium hydroxide on the material surface, which in turn produces hydroxyapatite in the presence of phosphate-containing fluids [6], [7]. Portland cement mixed with water, results in a granular and sandy paste with unfavorable handling characteristics that precludes the use of mineral trioxide aggregate (MTA) as a root canal sealer. Therefore, a number of studies have been performed attempting to develop a root canal sealer based on Portland cement [8], [9]. Since MTA and Portland present a similar chemical composition and biological response, experimental root canal sealer (MTA Sealer), containing white Portland cement, additive (calcium chloride) and a resinous vehicle, which conferred viscosity to the sealer, have been developed and their physicochemical and biological properties showed promising results [10], [11]. Nano particles and nano fibers have a wide range of applications in composites production. Nano-sized particles have a high surface to volume ratio that could lead to severe potential for chemical reactivity. Nanoparticles could serve as: centers for cement phases, centers for increasing cement hydration due to their high reactivity potential, reinforcements and fillers to increase density and decrease porosity of the composite [12], [13].

In this study, engineered cementitious based composites based on Portland cement were prepared using polypropylene fibers and for improving strength and flow of this kind of composite, silica and alumina nanoparticles were used.

Amir Mahmoudi is with the Sama Technical and Vocational Training College, Islamic Azad University, Saveh Branch, Saveh, Iran (phone: +98-9121852707; fax: +98-21-44201061; e-mail: amirmahmoudi1359@yahoo.com).

II. Experimental Procedure

A. Materials

Portland cement type II (density = 3.15 g/cm3) and microsilica powder with specific area of 20 m2/g and particle diameter of 0.2 mµ was purchased from Vand Chemie Co. Nano silica used in this study had particle size between 10-20 nm and 2.2-2.6 g/cm3density and was provided from Aldrich-Sigma Co. Nano-alumina (alpha type with particle size of 150 nm) Was purchased from Inframat Co. Polypropylene fibers used in this study are the standard ASTM C1116 and their specifications are listed in Table I. Mechanical and physical properties of the Polyethylene and polyvinyl alcohol fibers used in this study are listed in Table II.

Different percentages of materials used in different prepared samples are presented in Table III.

Preparation of composites engineering process is as follows: Firstly, sand with appropriate size was added to the Portland cement. All ingredients except water, stirred for a period of 270 seconds and then a little water was added to the mixture. In the next step the samples poured in the molds and vibrated for 2 minutes. Samples were kept in the mold for a day and then removed and were placed in a steam bath (T = 60 °C) for 7 days. Finally samples were removed from the bath and were subjected to the compressive test.

B. Slump Flow Ability Test

To evaluate the flow ability and filling ability of the prepared composite, slump flow test was used. In this test, the flow ability is measured by measuring the diameter of the composite mixture and the flowing time after removal of the slump cone. The following instruments were used in this test: Frustum with dimensions of 10 cm small diameter, 20 cm large diameter and 30 cm height as standard 2-12350.

Base plate made up of a hard material, non-absorbent and completely flat with dimensions of 90 × 90 cm2. Fig. 1 shows the dimensions of the instruments used in the slump flow test.

TABLE I
PHYSICAL AND MECHANICAL PROPERTIES OF POLYPROPYLENE FIBERS

Melting point (°C)	Diameter (µm)	Length (mm)	Tensile strength (N/mm²)	Young modulus (kg/cm³×10⁵)	Density (g/cm³)	Appearance	fiber
160	20	12	350	0.5	0.91	Smooth and white	polypropylene

TABLE II
PHYSICAL AND MECHANICAL PROPERTIES OF POLYETHYLENE AND POLYVINYL ALCOHOL FIBERS

(µm) Diameter	(mm) Length	(MPa) strength	(GPa) Young modulus	fiber
39	12	1620	42.8	PVA
38	38	2400	66	PE

TABLE III
DIFFERENT PERCENTAGES OF MATERIALS USED IN DIFFERENT PREPARED SAMPLES

sample	Cement(%)	Sand (%)	microsilica(%)	Water(%)	Superplasticizer(%)	(%)fibers			(%)nanosilica	Nano alumina (%)
						PP	PVA	PE		
1	27	22	33	16.3	-	-	-	-	-	-
2	27	22	33	16.3	0.4	-	-	-	-	-
3	27	22	33	16.3	0.4	1.3	-	-	-	-
4	27	22	33	16.3	0.4	1.6	-	-	-	-
5	27	22	33	16.3	0.4	1.3	-	-	1	-
6	27	22	33	16.3	0.4	1.3	-	-	2	-
7	27	22	33	16.3	0.4	1.3	-	-	3	-
8	27	22	33	16.3	0.4	1.3	-	-	4	-
9	27	22	33	16.3	0.4	1.3	-	-	-	1
10	27	22	33	16.3	0.4	1.3	-	-	-	2
11	27	22	33	16.3	0.4	1.3	-	-	-	3
12	27	22	33	16.3	0.4	1.3	-	-	-	4
13	27	22	33	16.3	0.4	1.3	-	-	3	2
14	27	22	33	16.3	0.4	-	-	1.3	-	-
15	27	22	33	16.3	0.4	-	1.3	-	-	-
16	18.7	22	33	16.3	0.4	1.3	-	-	-	-
17	27	22	33	16.3	0.4	-	-	-	1	-
18	27	22	33	16.3	0.4	-	-	-	2	-
19	27	22	33	16.3	0.4	-	-	-	3	-
20	27	22	33	16.3	0.4	-	-	-	4	-
21	27	22	33	16.3	0.4	-	-	-	-	1
22	27	22	33	16.3	0.4	-	-	-	-	2
23	27	22	33	16.3	0.4	-	-	-	-	3
24	27	22	33	16.3	0.4	-	-	-	-	4

The cone was placed in the center of the base plate and the prepared composite was poured into the cone. After filling the cone completely, the cone was pulled upward with a constant rate. After this moment the time of reaching to the radius of 50cm was recorded.

C. Compressive Strength Test

To measure the compressive strength of composites, Vertical force was applied to the prepared samples with constant speed by ELE made in England. Test was done based on ASTM C39 standard.

III. RESULTS AND DISCUSSION

A. Slump Flow Ability Test

The diameter of the circle created by composite spreading represents filling ability and flow ability of the samples. Another parameter that is measured in the slump flow test is the time to reach the radius of 50 cm (T_{50}) that represents viscosity of the samples. If the mixture reaches to 50 cm diameter in more than 5 seconds, the viscosity is high but if the mixture reaches to 50 cm diameter in less than a second, the viscosity is low. Results showed that with increasing nanoparticle percentage in the samples, slump flow diameter decreases (Fig. 2). Nanoparticles of silica and alumina, increases the yield stress and viscosity of the prepared composites, due to their high reactivity. With increasing of nanoparticles, the time to reach the radius of 50 cm increased. Fig. 3 shows the slump flow diameter of the samples containing of nanofibers and samples without nanofibres. As can be seen in Fig. 4 Addition of fiber to the composites decreased the flow ability and increased viscosity of the samples thus slump flow diameter decreased.

Figs. 4 and 5 show the effects of addition of both nanoparticles and fibers on flow ability of the prepared composites. It is observable that addition of nanoparticles and fibers has reduced flow ability of the samples. As in previous cases, with increasing nanoparticle slump flow diameter decreased and T_{50} increased also the reduction in flow ability was greater than the sample containing only nanoparticle or fibers.

International Journal of Architectural, Civil and Construction Sciences
ISSN: 2415-1734
Vol:9, No:3, 2015

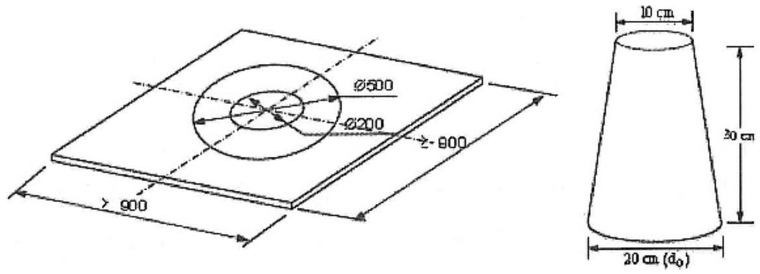

Fig. 1 Dimensions of slump cone and base plate used in slump flow test

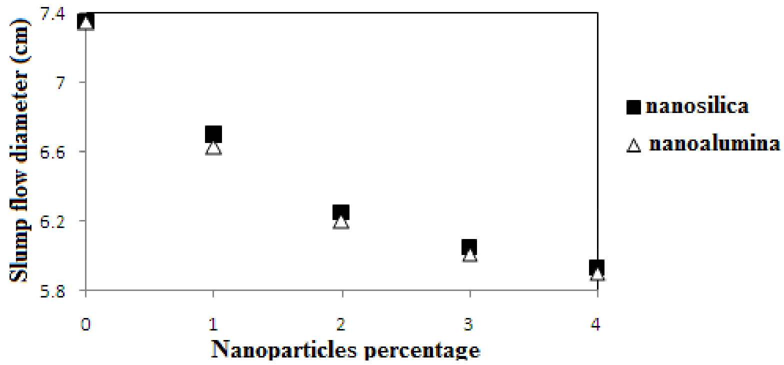

Fig. 2 The effect of nanoparticle percentage on slump flow ability of the prepared composite

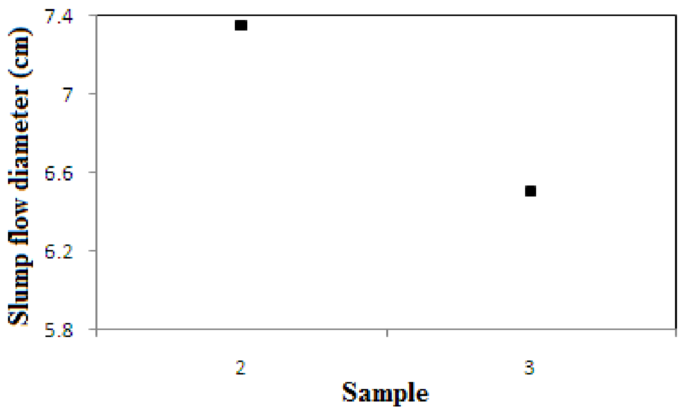

Fig. 3 The effect of addition of poly propylene nanofibers on slump flow ability of the prepared composite

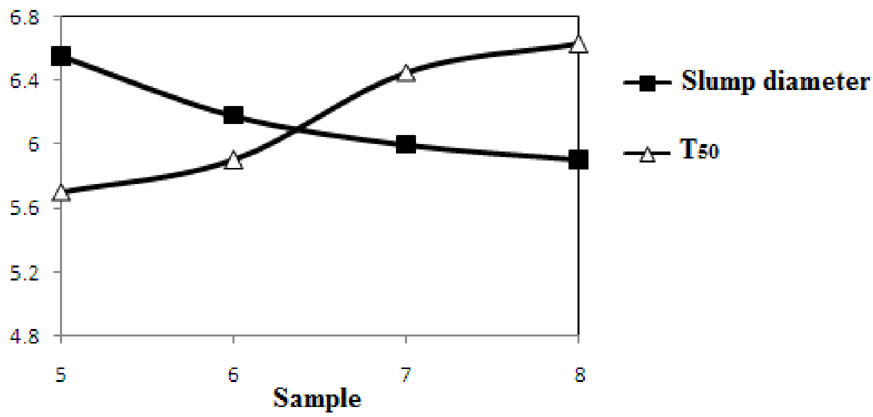

Fig. 4 Slump flow diameter and T_{50} of the samples containing both silica nanoparticles and fibers

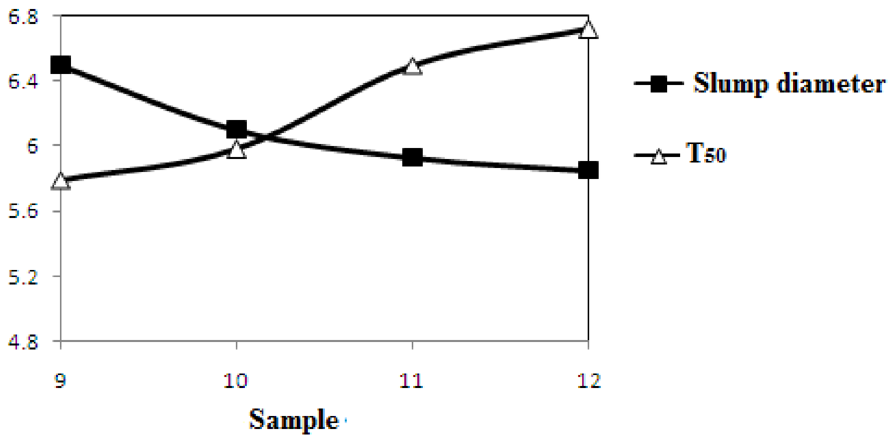

Fig. 5 Slump flow diameter and T_{50} of the samples containing both alumina nanoparticles and fibers

B. Compressive Strength

Fig. 6 shows compressive strength of the samples containing nanosilica. Superior compressive of the samples containing nanosilica rather than the others could be due to the rapid consumption of calcium hydroxide produced by the hydration of Portland cement [13]. Therefore, nanoparticles accelerate cement hydration. The compressive strength of the samples increased with addition of silica and alumina nanoparticles up to 3% and after decreased. This is because of that increasing nanoparticles more than 3% increases agglomeration of the particles and decreases compressive strength of the samples [14], [15].

Compressive strength of the samples containing alumina nanoparticles is shown in Fig. 7 alumina nanoparticles increases compressive strength like silica nanoparticles. The reduction in compressive strength after a maximum of 2% alumina nanoparticles percentage is due to Agglomeration of alumina nanoparticles, resulting in the partial hydration of cement particles.

Samples containing both silica nanoparticles and fibers had the highest strength that shows fibers can serve as an increasing of strength factor. In fact Fibers produce residual stress in the samples that increases compressive strength of the samples (Fig. 8).

IV. Conclusions

Cementitious composites based on Portland cement could serve as canal sealers due to their proper biological properties. The goal of this study is to investigate the effects of adding silica and alumina nanoparticles on flow ability and compressive strength of the cementitious composites based on Portland cement to be used in biomedical applications. With increasing of nanoparticle percentage in the prepared samples, slump flow diameter decreased that this reduction in slump flow diameter was higher for samples containing alumina nanoparticles rather than the samples containing silica nanoparticles. Also, with increasing the ratio of micro silica to cement from 2.1 to 2.2, the slump flow diameter increased.

By adding silica and alumina nanoparticles up to 3% and 2% respectively, the compressive strength increased and after decreased. Addition of fibers created residual stress that increased compressive strength of the samples.

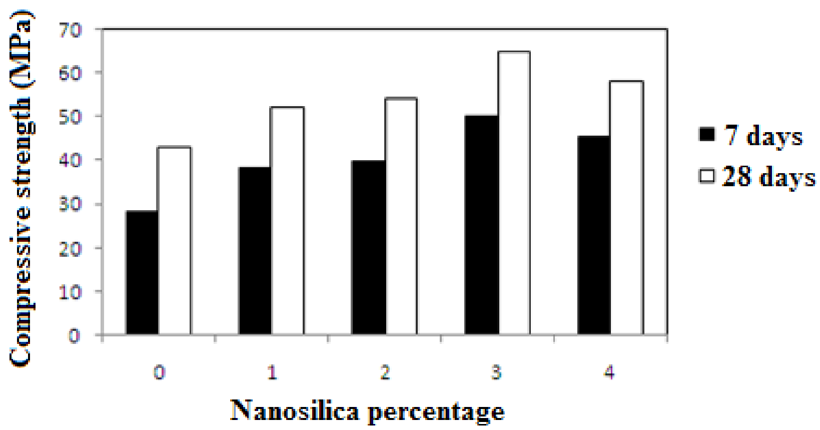

Fig. 6 Compressive strength of the samples with different nanosilica percentage

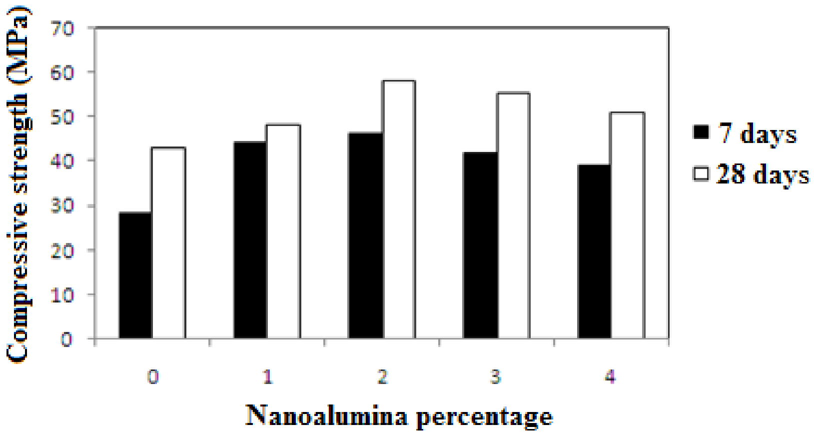

Fig. 7 Compressive strength of the samples with different nanoalumina percentage

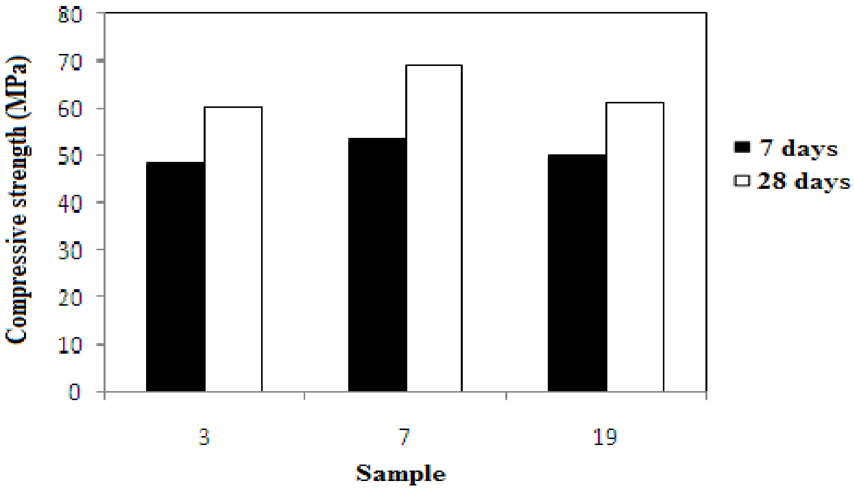

Fig. 8 Compressive strength of different samples, (3) containing fibers, (7) containing fibers and nanosilica, (19) containing nanosilica.

REFERENCES

[1] Nazari, S. Riahi, Al_2O_3 nanoparticles in concrete and different curing media, Energy and Buildings, 43, 2011, 1480-1488.

[2] B. W. Jo, C. H. Kim, G. H. Tae, and J. B. Park, *Characteristics of cement mortar with nano-SiO_2 particles*, Construction and Building Materials, 21, 2007, 1351-1355.

[3] W. Y. Kuo, J. S. Huang, C. H. Lin, Effects of organo-modified montmorillonite on strengths and permeability ofcement mortars, Cement and Concrete Research, 36, 2006, 886 – 895.

[4] J. Chen, S. C. Kou, C. S. Poon, Hydration and properties of nano-TiO_2 blended cement composites, Cement & Concrete Composites, 34, 2012, 642–649.

[5] L. Raki, J. Beaudoin, R. Alizadeh, J. Makar, T. Sato, *Cement and Concrete Nanoscience and Nanotechnology*, Materials, 3, 2010, 918-942.

[6] D. Abdullah, T.R. Pitt Ford, S. Papaioannou, J. Nicholson, F. McDonald, An evaluation of accelerated Portland cement as a restorative material, Biomaterials, 23, 2002, 4001-4010.

[7] M.G. Gandolfi, F. Perut, G. Ciapetti, R. Mongiorgi, C. Prati, New Portland Cement–based Materials for Endodontics Mixed with Articaine Solution: A Study of Cellular Response, Journal of Endodontics, 34, 2008, 39-44.

[8] A.L. Gomes Cornélio, L.P. Salles, M. Campos da Paz, J.A. Cirelli, J.M. Guerreiro-Tanomaru, M. Tanomaru Filho, Cytotoxicity of Portland Cement with Different Radiopacifying Agents: A Cell Death Study, Journal of Endodontics, 37, 2011, 203-210.

[9] D.A. Ribeiro, M.A.H. Duarte, M.A. Matsumoto, M.E.A. Marques, D.M.F. Salvadori, Biocompatibility In Vitro Tests of Mineral Trioxide Aggregate and Regular and White Portland Cements, Journal of Endodontics, 31 (2005) 605-607.

[10] S. Shahi, S. Rahimi, H.R. Yavari, H. Mokhtari, L. Roshangar, M.M. Abasi, S. Sattari, M. Abdolrahimi, Effect of Mineral Trioxide Aggregates and Portland Cements on Inflammatory Cells, Journal of Endodontics, 36, 2010, 899-903.

[11] N. Wongkornchaowalit, V. Lertchirakarn, Setting Time and Flowability of Accelerated Portland Cement Mixed with Polycarboxylate Superplasticizer, Journal of Endodontics, 37, 2011, 387-389.

[12] M. D. Lepech, V. C. Li, Water permeability of engineered cementitious composites, Cement & Concrete Composites, 31, 2009, 744-753.

[13] M. Şahmaran, V. C. Li, De-icing salt scaling resistance of mechanically loaded engineeredcementitious composites, Cement and Concrete Research, 37, 2007, 1035-1046.

[14] A. Spagnoli, A micromechanical lattice model to describe the fracture behaviour ofengineered cementitious composites, Computational Materials Science, 46, 2009, 7-14.

[15] C. Panganayi, H. Ogata, K. Hattori, Effect of plate thickness on crack propagation characteristics of engineered cementitious composites, Asian Journal of Applied Sciences, 4, 2011, 542-547.