International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 13 (2018) pp. 11183-11188

Effect of Nano Silica on the Fresh and Hardened Properties of Cement Mortar

Akash Kumar, Gurpreet Singh

Civil Engineering, Chandigarh University, Mohali, Punjab, India

Abstract

This research study shows the effect of Nano silica on fresh properties, hardened properties of cement mortar.in recent studies, researchers found that up to 3.5% Nano silica increase the strength of cement mortar for 0.35 water to binder ratio. Nano silica particles size of .2 to .3 microns have been used with replacement of cement by 1%, 2%, 3%, 4%, 5% and 6% by weight of cement content. Results indicated that setting time increase with increasing Nano silica addition. Nano silica improves fresh and hardened properties of cement up to 5% then the strength starts decreasing. Nano silica enhance more strength at the early age than later age.

Keywords: cement mortar, Nano silica, initial setting time, final setting time, flow table test, compressive strength and split tensile strength.

INTRODUCTION

Cement mortar is a composite material obtained by adding fine aggregate and water into cement. Cement mortar used as a binder material in brickwork and stonework from last two century. Cement mortar used in plastering on brickwork, stonework and on concrete work. From the study of the great pyramid of Egypt, it was found that mortar used to build it had 81.5% calcium sulfate and 9.5% carbonate. Due to increase in population, it is required to increase the strength and durability properties to save land for agriculture to complete other requirements of the human being. To do so, we have to make more story building to accomplish this goal. Main components of mortar are cement and fine aggregate. Cement is a binder material which is used to bind fine aggregates when mixed with water. Ordinary Portland cement is used obtained from limestone quarried from Isle of Portland in England. Aggregate have a significant effect on mechanical properties of cement mortar like compressive strength and split tensile strength. In mortar fine aggregates are used obtained from the river bed and passed from 4.75 mm sieve. in the recent years, the use of Nanoparticles has received particular attention in many fields of application to fabricate materials with new functionalities. When nanoparticles are incorporated into Portland cement paste, mortar, materials with different characteristics from conventional materials were obtained. The performance of these cementitious based materials is strongly dependent on Nano size solid particles, such as particles of calcium silicate hydrates, Nanosized solid porosity at the interfacial zone between cement and sand particles. Typical properties affected by Nano-sized particles are strength, durability, and shrinkage. Nanoparticles of sio_2 can fill the space between particles of the gel of calcium silicate hydrate, acting as Nano filler. The particles of calcium silicates hydrate at the interfacial transition zone between cement and fine aggregate. The Nano silica decreasing the setting time when comparing with the silica fume. The effect of Nano silica addition on cement mortar decrease water permeability and improves microstructure. Different cement mortar mixes were evaluated incorporating Nano silica particles of 10mm to 20mm. The result can show that Nano silica can improve microstructure and reduces the water permeability for hardened cement mortar. The most effective of Nano silica is the impact on the mechanical properties of cement mortar. And the Nano silica content increases the density and reduces the porosity and improves the bond between the fine aggregate and cement matrix. The addition of Nano silica in cement mortar shows higher compressive strength and high split tensile strength when compared with plain cement mortar.

LITERATURE REVIEW

P. Di Maida et.al., (2015) studied the effect of powdered and colloidal Nano-silica on the properties of cement mortar. SEM and XRD displayed that the powder Nano silica is amorphous while colloidal is agglomerated in nature. Approximately 27 and 37% enhancement in the compressive strength was observed using colloidal Nano-silica while there was only 19 % increase in the compressive strength when powdered Nano silica was used. L.P. Singh et.al., (2013) presented review on the effects of Nano-silica on hydration, refinement of microstructure, fresh properties, strength properties and durability of cement. Authors concluded that dispersion of Nano-silica should be studied and adequate dispersion mechanism of Nano-silica is required. The optimum percentage for the replacement with Nano-silica cannot be fixed as it depends on the type of Nano-silica like whether it is colloidal or dry powder and it also relies on. Sayed et.al., (2013) Nano-silica particles with the size of 19 nm have been used as a cement addition by 1, 3, 5, 7 and 10 % by weight of cement content. Results designated that the cement mortar workability decrease with increasing Nano-silica adding. On the other hand, the percentage of 7 % of Nano-silica recorded as the optimum percentage in compressive and flexure strength measured for cement mortar mixed with the Nano-silica. The

enhancement in compressive and flexure strength measured as 55.7 % and 46.9 % correspondingly, compared with the conventional mortar, particularly at early ages. Min. Hong Zhang et.al. (2012) studied the effect of Nano silica and high-volume slag mortar on setting time and early strength and observed that rate of hydration increases with the addition of Nano silica, the compressive strength of slag mortar increases with increase in Nano silica dosages from 0.5 to 2% by weight of cement. 2% Nano-Silica reduces initial and final setting time and compressive strength increases by 22% and 18% at 3 days and 7 days with the addition of 50% slag. NS with particle size 7 & 12 nm is more effective in increasing cement hydration and reaction compared with silica fume. Peng-kun A.M. Said et.al., (2012) studied the combined effects of Colloidal Nano-silica and fly ash on cement mortars. Nano-silica used was of the 10nm size and the class F fly ash was used. Results obtained showed that the colloidal Nano-silica decreases the setting time of cement with fly ash. G. Quercia et.al., (2011) compared and analyzed six different silica samples with flow test and the thickness of 25nm water layer was computed. It was shown by granular analysis water demand of the cement mortar can be decreased by adding Nano-silica. Authors also concluded that the water demand can be reduced by addition of 0.5-4.0% by weight without any superplasticizers. Also, research should be done to modify the conventional Nano-silica so that it can be used in mass. It was found that Higher deformation coefficients for the specimen with Nano-silica were bigger than cement. A. Sadrmotazi et.al. (2010), in another paper, have studied the effect of Polypropylene fibers along with Nano Silica particles. The Nano silica was replaced up to 7% which enhanced the compressive strength of cement mortar by 6.49%. Polypropylene fibers amount beyond 0.3% reduces the compressive strength but beyond 0.3% dose of Polypropylene fibers increases the flexural strength, showing the effectiveness of Nano-Silica particles. Also, up to 0.5% Polypropylene fibers in mortar water absorption decreases which indicates pore refinement. Blyszko et.al., (2008) examined the influence of Nano-silica and micro silica on properties like compressive strength, porosity, absorption and weight loss of cement mortars up to 28 days. The percentage varied from 0-7% for Nano silica and 0-20% for silica fumes by weight and water to binder ratio 0.35 to 0.59. Out of this Nano silica with 7% weight showed faster CSH gel formation. In the case of Nano silica, the unrestrained shrinkage was increased to 80 % at 7 days as compared to silica fumes was at 54% at 28 days. Authors concluded that specimens with 7% Nano-silica has better microstructure. The properties were considerably improved. Authors advised to studying the specific samples with the more restricted interval for 0.35 Water content the porosity and absorption had maximum values for 7% Nano-silica. B.-W Jo et. al. (2007) studied the characteristics of cement mortar with Nano Silica particles experimentally and observed the higher strength of these blended mortars for 7 and 28 days. The microstructure analysis displayed that Nano silica not only acts as a filler to advance microstructure but act as an activator to the pozzolanic reaction.

MATERIALS AND METHODS

The cement used in this study is Ordinary Portland Cement is used for the cement mortar cubes. Aggregate used are collected from river bad having 2.72 g/mm^3 specific gravity and fineness modulus 2.26. The Nano silica is used as the pozzolanic material in this study to improve fresh and hardened properties of the cement mortar. The properties of Nano silica are described in Table-1.

Table 1: Properties of Nano silica

Property	Result
B.E.T. Surface Area	200 m2/g
Wt. per gallon	18.3 lb
pH (4% aqueous slurry)	3.7–4.3
325 Mesh Residue (44 microns)	0.02% max.
Bulk Density	3.0 lb/ft3 max.
Loss on Heating	1.5% max.
Loss on Ignition (@ 1000ºC)	2 wt. %
Specific Gravity	2.2 g/cm^3
Average Particle Length	0.2–0.3 microns
Oil Adsorption	350 g/100 g oil
X-ray Form Amorphous (% SiO2)	99.8
Refractive Index	1.46

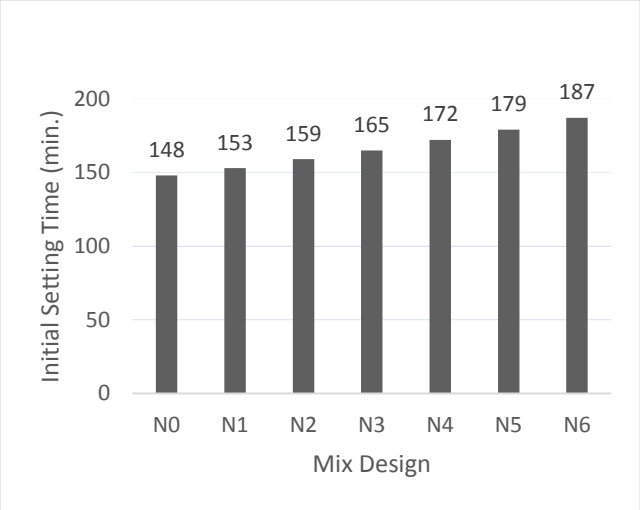
Mix Proportioning and Curing: The seven different percentage of silica used by weight of the cement. The percentages are 0%, 1 %, 2%, 3 %, 4%, 5 % and 6 % of Nano silica is replaced by weight of the cement. The water to cement ratio 0.32 and 0.37 are taken.

Sample Preparation and Testing: The mortar cube of specimen size is 70.6 x 70.6 x 70.6 mm were cast for determining the compressive strength and split tensile strength for Ordinary Portland cement with and without Nano silica. The casted specimen should be tested at 7days, 14days and 28days strength.

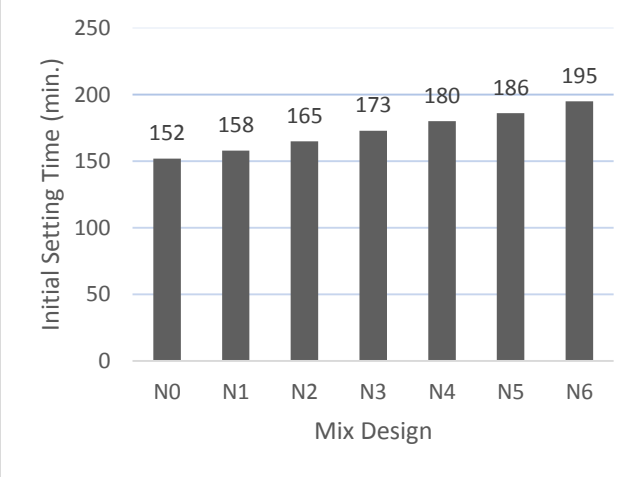
RESULTS AND DISCUSSION

Initial Setting Time:

Initial setting time for cement mortar is shown in below for 0.32 and 0.37 water to binder ratio.



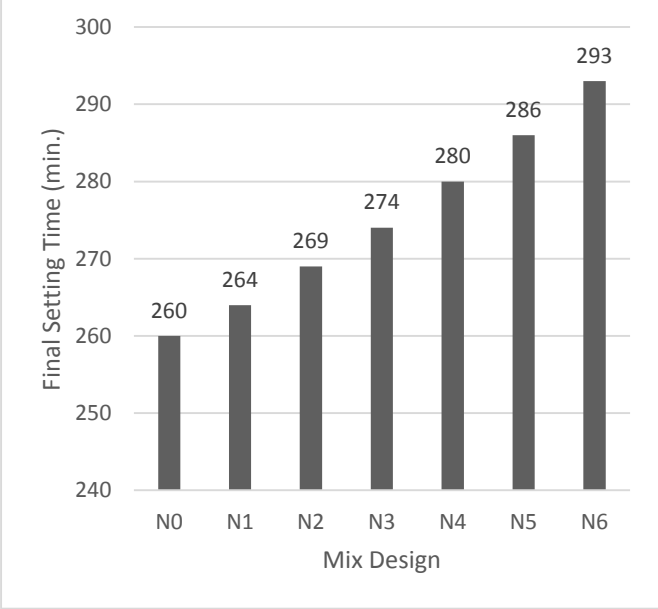
Water to Binder Ratio 0.32



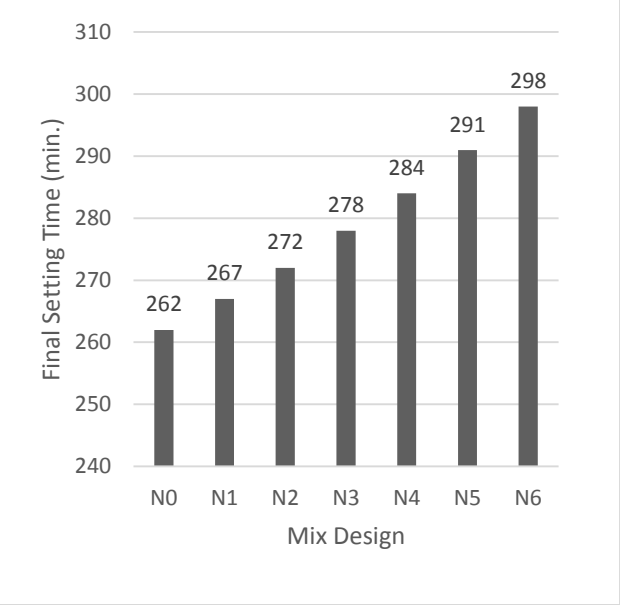
Water to Binder Ratio 0.37

Final Setting Time

Final setting time for cement mortar is shown below for 0.32 and 0.37 water to binder ratio.



Water to Binder Ratio 0.32



Water to Binder Ratio 0.37

Flow table test:

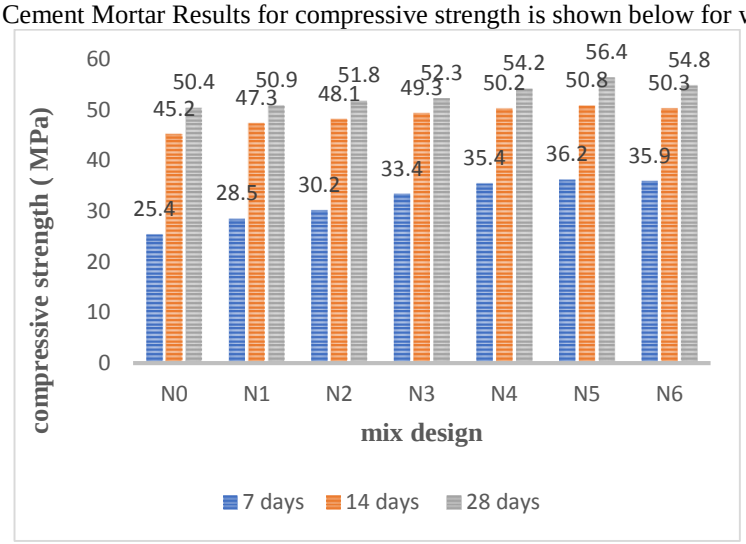
Flow table test is conducted to find out the percentage of superplasticizer to add to the mix to maintain the workability of the mix.

Table 2: Cement Mortar Results for flow table test:

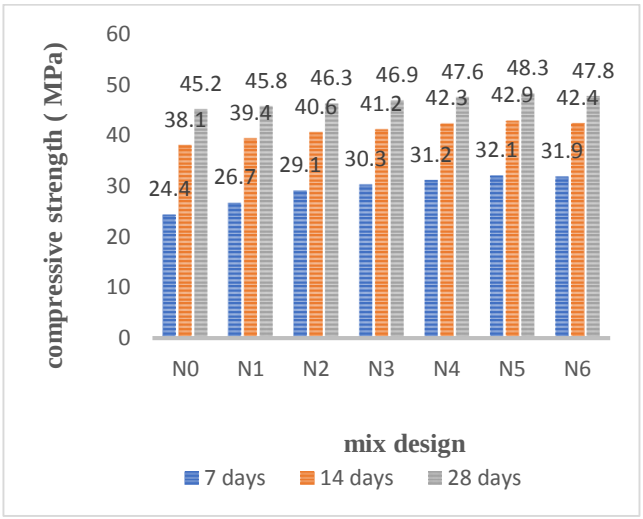
Mix design	Cement	For 0.32 Water to binder ratio				For 0.37 Water to binder ratio			
		Fine aggregate	Water	Super plasticizer	Nano silica	Fine aggregate	Water	Super plasticizer	Nano silica
N0	150	280	48	2	0	360	55.5	1	0
N1	148.5	280	48	3	1.5	360	55.5	2	1.5
N2	147	280	48	4	3	360	55.5	3	3
N3	145.5	280	48	5	4.5	360	55.5	4	4.5
N4	144	280	48	6	6	360	55.5	5	6
N5	142.5	280	48	7	7.5	360	55.5	6	7.5
N6	141	280	48	8	9	360	55.5	7	9

Compressive strength:

Cement Mortar Results for compressive strength is shown below for water to cement ratio 0.32 and 0.37.

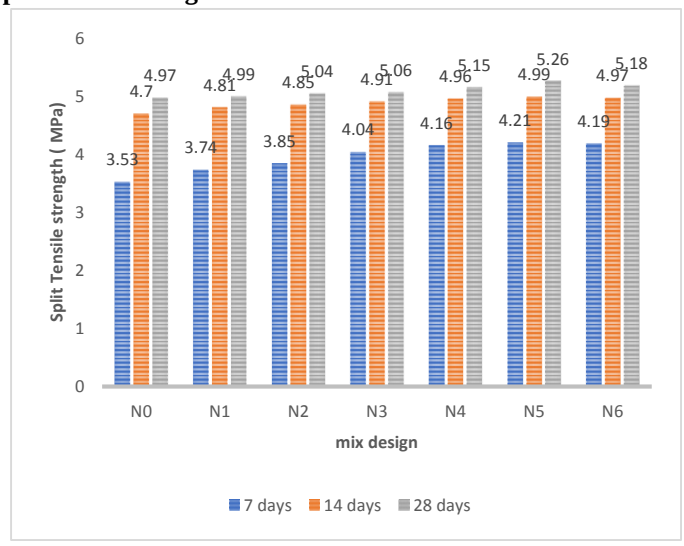


water to binder ratio 0.32

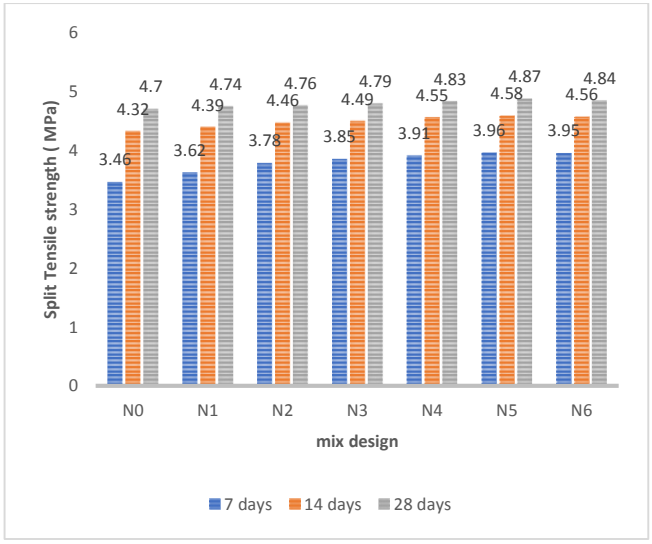


water to binder ratio 0.37

Split tensile strength:



water to binder ratio 0.32



water to binder ratio 0.37

It shows that the addition of 5 % of Nano silica gives the high split tensile strength at 7days, 14days and 28 days strength when comparing to the conventional mortar cubes.

CONCLUSION

From the test results, a number of conclusions can be drawn. These conclusions are justified in the next section. The conclusions drawn are:

i. From the compressive strength results, it can be observed that increase in compressive strength of cement mortar is observed on addition of a certain minimum quantity of Nano-Silica. The increase in strength is maximum for Nano silica 5% by weight of cement.

ii. On addition of Nano-Silica, there is a substantial increase in the 7 days strength of cement mortar compared to the 28 days increase in strength.

iii. Workability of cement mortar decreased by increasing the amount of Nano silica.

iv. Cement mortar containing Nano silica have more homogeneity binder and fewer pores than cement mortar without Nano silica.

v. The consistency and setting time is decreased with increase in Nano silica amount.

REFERENCE

[1]. N Retno Setiati, Effects of additional Nano silica of compressive strength on mortar, *Materials Science and Engineering, 223, 2017, 1-12.*

[2]. Ehsan Ghafari, Hugo Costa, Eduardo Júlio, António Portugal, Luisa Durães, The effect of Nano silica addition on flowability, strength and transport properties of ultra high-performance concrete, *Elsevier- Materials and Design, 59, 2015, 1–9.*

[3]. Ehsan Mohseni, Bahareh Mehdizadeh Miyandehi, Jian Yang, Mohammad Ali Yazdi, Single and combined effects of Nano-SiO2, Nano-Al2O3 and Nano-TiO2 on the mechanical, rheological and durability properties of self-compacting mortar containing fly ash, *Elsevier- Construction and Building Materials, 84, 2015, 331–340.*

[4]. M. Sonebi, E. García-Taengua, K.M.A. Hossain, J. Khatib, M. Lachemi, Effect of Nano silica addition on the fresh properties and shrinkage of mortars with fly ash and superplasticizer, *Construction and building materials, 84, 2015, 269 – 276.*

[5]. P. Di Maida, E. Radi, C. Sciancalepore, F. Bondioli, Pullout behavior of polypropylene macro-synthetic fibers treated with Nano-silica, *Elsevier- Construction and Building Materials, 82, 2015, 39–44.*

[6]. Sakshi Gupta, Use of triangular membership function for prediction of compressive strength of concrete containing Nano silica, *Cogent Engineering, 2, 2015, 1-11.*

[7]. G. Dhinakaran, A. Rajasekharareddy, B. Kartikeyan, K. Sumanth and G. Harshavardhan, Microstructure analysis and strength properties of concrete with Nano SiO2. *International Journal of Chemtech Research CODEN, Vol.6, No.5, 2014, 3004-3013.*

[8]. Mukharjee, Bibhuti Bhusan, Barai and Sudhirkumar V., Influence of incorporation of Nano-silica and recycled aggregates on compressive strength and microstructure of concrete. *Construction and Building Materials 71, 2014, 570-578.*

[9]. Pengkun Hou, Jueshi Qian, Xin Cheng, Surendra P. Shah, Effects of the pozzolanic reactivity of NanoSiO2 on cement-based material, *Elsevier- Cement & Concrete Composites 55, 2014, 250-258.*

[10]. R. Yu, P. Tang, P. Spiesz, H.J.H. Brouwers, A study of multiple effects of Nano-silica and hybrid fibers on the properties of Ultra-High-Performance Fiber-Reinforced Concrete incorporating waste bottom ash, *Elsevier- Construction and Building Materials, 60, 2014, 98–110.*

[11]. L.P. Singh, S.R. Karade, S.K. Bhattacharyya, M.M. Yousuf, S. Ahalawat, Beneficial role of Nano silica in cement-based materials – A review, *Elsevier Construction and Building Materials, 47, 2013, 1069–1077.*

[12]. Maheswaran S., Bhuvaneshwari B., Palani G.S., Nagesh R Iyer, Kalaiselvam S, An Overview on the Influence of Nano-Silica in Concrete and a Research Initiative, *Research Journal of Recent Sciences, 2, 2013, 17-23.*

[13]. Sayed abd EL-Baky, Sameh Yehia, Ibrahim S. Khalil, Influence of Nano silica addition on properties of fresh and hardened cement mortar, *Nanocon brno Czech Republic eu, Oct 16-18 2013.*

[14]. A.M. Said, M.S. Zeidan, M.T. Bassuomi and Y. Tian., Properties of concrete incorporating Nano-silica. *Construction and Building Materials 36, 2013, 838-844.*

[15]. Alireza Naji Givi ,Suraya Abdul Rashid,Farah Nora A. Aziz &Mohamad Amran Mohd Salleh, Influence of 15 and 80 nano-SiO2 particles addition on mechanical and physical properties of ternary blended concrete incorporating rice husk ash. *Journal of Experimental Nanoscience, vol.8, 2012, 1-18.*

[16]. Heidari, A., and Tavakoli, D., A study of mechanical properties on ground ceramic powder concrete incorporating Nano SiO2 particles. *Construction and Building Materials Vol. 38, 2012, 255-264.*

[17]. J. Camiletti, A.M. Soliman, M.L. Nehodi, Effect of Nano and Micro limestone addition on early age properties of ultra-high-performance concrete, *Materials, and structures, vol 45, 2012.*

[18]. Min-Hong Zhang, Jahidul Islam and others, Use of Nano-Silica to increase early strength and reduce setting time of concrete with high volume slag,

Cement and concrete composites, Vol 34, 2012, 650-662.

[19]. L. Senffa, D. Hotza, S. Lucas, V.M. Ferreira, J.A. Labrincha, Effect of Nano-SiO2 and Nano-TiO2 addition on the rheological behavior and the hardened properties of cement mortars, *Elsevier- Materials Science and Engineering, 532, 2012, 354–361*.

[20]. Pengkun Hou, Shiho Kawashima, Deyu Kong, David J. Corr, Jueshi Qian, Surendra P. Shah, Modification effects of colloidal NanoSiO2 on cement hydration and its gel property, *Elsevier-composites, 45, 2013, 440-448.*

[21]. Ali Nazari, Shadi Riahi, Shirin Riahi, Saydeh Fatemeh Shamekhi and A. Khademno. Improvement of the mechanical properties of the cementitious composites by using TiO2 nanoparticles. *Journal of American Science 6(4), 2012, 98-101.*

[22]. G, Quercia, G. Hüsken, H.J.H Brouwers, Water demand of amorphous Nano silica and its impact on the workability of cement paste, *Cement Concrete Research, 42, 2011, 344–357.*

[23]. Meral Oltulu, Remzi S¸ ahin, Single and combined effects of Nano-SiO2, Nano-Al2O3 and Nano-Fe2O3 powders on compressive strength and capillary permeability of cement mortar containing silica fume, *Elsevier- Materials Science and Engineering, 528, 2011, 7012– 7019.*

[24]. Shekari, A. H. and Razzaghi, M., Influence of nanoparticles on durability and mechanical properties of SCC with GGBFS as binder. *Energy and buildings Vol. 43, 2011, 995-1002.*

[25]. Givi, A. N. and Rashid, S. A., The effect of lime solution on the properties of SiO2 nanoparticles binary blended concrete. *Composites (Part B) Vol. 42, 2011, 562-569.*

[26]. V. Ershadi, T. Ebadi, A.R Rabani, L. Ershadi, H., The Effect of Nano silica on Cement Matrix Permeability in Oil Well to Decrease the Pollution of Receptive Environment, *Soltanian International Journal of Environmental Science and Development, Vol. 2, No. 2, April 2011.*

[27]. Alireza Naji Givi, Suraya Abdul Rashid, Farah Nora A. Aziz, Mohamad Amran Mohd Salleh, Experimental investigation of the size effects of SiO2 Nanoparticles on the mechanical properties of binary blended concrete, *Elsevier Composites: Part B 41, 2010, 673–677.*

[28]. Ali Nazari, Shadi Riahi, Shirin Riahi, Saydeh Fatemeh Shamekhi and A. Khademno., Embedded ZrO2 nanoparticles mechanical properties monitoring in cementitious composites. *Journal of American Science 6(4), 2010, 86-89.*

[29]. A. Sadrmomtazi, and A. Fasihi, Influence of Polypropylene fibers on performance of Nano- Si02 incorporated mortar, *Iranian Journal of science and technology. Vol 34, 2010, 385-395.*

[30]. G. querica, H.J.H. Brouwers, application of Nano silica in concrete mixtures, *8thfib PhD symposium in kgs. Lyngby, Denmark, June 20-23, 2010.*

[31]. M.Collepardi, J.J. Ogoumah and others, Combination of Silica fume, fly ash, and amorphous Nano silica in super plasticized HPC, *Engineering concrete research –Italy 2010.*

[32]. M.S. Morsy, S.H. Alsayed and M. Aqel., Effect of Nano clay on mechanical properties and microstructure of Ordinary Portland Cement mortar. *International Journal on Civil Engineering & Environmental Engineeering, Vol 10, 2010*, 01-43.

[33]. Belkowitz, J., Armentrout, D., An Investigation of Nano-silica in the Cement Hydration Process, *American concrete institute, SP267-08, 2009, 87-100.*

[34]. Nilli, M., Ehsani, A. and Shabani, K., Influence of Nano SiO2 and micro silica on concrete performance. *Bu-Ali Sina University Iran*. 2009.

[35]. N. Guskos, G. Zolnierkiewicz, A. Guskos, J. Typek, J. Blyszko, W. Kiernozycki, U. Narkiewicz, M. Podsiadly, Magnetic properties of the micro-silica/cement matrix with carbon-coated cobalt Nanoparticles and free radical DPPH, *Journal of Non-Crystalline Solids, 354, 2008, 4510-4514*.

[36]. Byung-Wan Jo, Chang-Hyun Kim, Ghi-ho Tae and Jang-Bin Park., Characteristics of cement mortar with nano-SiO2 particles. *Construction and Building Materials 21, 2007, 1351-1355.*

[37]. Ji Tao, Preliminary study on the water permeability and microstructure of concrete incorporating Nano-SiO2, *Cement and Concrete Research, 35, 2005, 1943–1947.*

[38]. Hui Li, Hui-gang Xiao, Jie Yuan and Jinping Ou., Microstructure of cement mortar with nanoparticles. *Composites: Part B 35, 2004, 185-189.*

[39]. IS:2386-1963 (Part-III). Methods of Test for aggregates for concrete Part III specific gravity, density, voids, absorption and bulking. *Bureau of Indian Standards.*

[40]. IS:383-1970. Specification for coarse aggregate and fine aggregate from natural sources for concrete. *Bureau of Indian Standards.*

[41]. IS:455-1989. Portland Slag Cement- Specification, *Bureau of Indian Standards.*