International Journal of Civil and Structural Engineering Research ISSN 2348-7607 (Online)
Vol. 5, Issue 2, pp: (81-85), Month: October 2017 - March 2018, Available at: www.researchpublish.com

Effect of Nano Silica on Fresh, Hardened and Durability Properties of Cement Mortar: A Review

[1]Akash Kumar, [2]Gurpreet Singh

[1, 2] Civil Engineering, Chandigarh University, Mohali, Punjab, India

Abstract: **In the present era Nano silica is the next big thing in civil engineering for advancement of cement structure. Many researchers and scientists have been developed a number of techniques to improve the fresh, hardened and durability properties. Engineers are continuously pushing the limits to improve the performance of cement structures with the help of supplementary cementitious materials. The present research work focused on Nano silica. The mortar was made by using Nano silica with partial replacement of ordinary Portland cement at various percentages 0% to 15%. Fresh properties (like initial setting time and final setting time), hardened properties (like compressive strength, split tensile strength and flexural strength) and durability properties.**

Keywords: **cement mortar, Nano silica, fresh properties, hardened properties and durability properties.**

1. INTRODUCTION

in the recent years, the use of Nano silica has received particular attention in field of cement mortar and cement concrete. When ultra fine particles are merged into Portland cement, mortar, concrete materials with different features from predictable materials were found. The performance of these pozzolanic based materials is mainly reliant on on Nano size solid particles, such as particles of calcium silicate hydrates, Nano sized solid porosity at the interfacial zone between cement and sand particles. Typical properties affected by Nano sized particles are strength, durability and shrinkage. Nano particles of sio_2 can fill the space between particles of gel of calcium silicate hydrates, acting as Nano filler. Furthermore, by the pozzolanic reaction with calcium hydroxide, the amount of calcium hydrates increases, resulting a higher densification of the matrix, which improves the strength and durability of the material. The particles of calcium silicates hydrates at the interfacial transition zone between cement and fine aggregate. The Nano silica decreasing the setting time when comparing with the silica fume.

Now days, there are diverse approaches to produce Nano silica products. One technique is based on a sol gel process at a room temperature. An another production method is vaporization of silica by reducing quartz at 1500 to 2000 ^{0}c. it was developed by iller in 1954. Nano silica particles are divided into p type and s type according to their structure. The p type particles are characterised by numerous Nano pores having a pore rate of 0.61 ml/g. the s type particles have a comparatively smaller surface area. The p type Nano silica particles exhibit a higher ultra violet reflectivity when compared to the s type.

The consequence of Nano silica adding on cement mortar decrease water permeability and advances microstructure. Different cement mortar mixes were assessed incorporating Nano silica particles of 10mm to 20mm. The result can show that Nano silica can improve micro structure and reduces the water permeability for hardened cement mortar. The most effect 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 plane cement mortar.

2. LITERATURE REVIEW

N Retno Setiati, (2017) study aims to determine the effect from the addition of Nano silica on mechanical properties of concrete. Laboratory testing is conducted by making the mortar test specimen size of 50 mm x 50 mm x 50 mm. The material used is composed of silica sand, Nano silica, gravel, superplasticizer, cement, and water. Nano silica percentage amount is added as much as 5, 10, and 15% by weight of cement. Testing of mechanical properties such as compressive strength mortar done at age 3, 7, 14, and 28 days. Based on the analysis and discussion obtained that at 28 days, mortar with the addition of 5% and 15% Nano silica has the compressive strength of 23 MPa. Addition Nano silica into the mortar to improve the mechanical properties by increasing the compressive strength of mortar. The compressive strength of mortar with the addition of 10% Nano silica is 19 MPa. The increase in compressive strength of mortar with the addition of 5% and 15% Nano silica is 21% larger than the mortar with the addition of 10% Nano silica and without Nano silica. Nano silica addition of more than 10% can cause agglomeration when mixed into the mortar so that the impact on the compressive strength of mortar.

Ehsan Ghafari et.al., (2015) studied the effect of Nano-silica on the properties of high performance concrete. Thermo gravimetric analysis showed that Nano-silica consumes Ca(OH)2 more than the micro silica at the early stages. The addition of Nano-silica results in decrease of capillary pores. The addition of Nano-silica enhances the interface between the aggregates and the binding paste. The compressive strength and the transport properties were increased by the addition of Nano-silica. 3% was the optimum amount of cement replacement with Nano-silica to obtain maximum performance. Authors concluded that compressive strength increased with the incorporation of Nano-silica in specially at the early stages.

Ehsan Mohsen et.al., (2015) analysed the influence of Nano-silica (5- 70 nm) on the physical properties of cement. The strength development of Portland cement with Nano-silica was studied. From tentative study of cement mortar with Nano-silica shows an enhancement in flexural and compressive strength was found. The addition of Nano-silica resulted in overall enhancement of cement mortar. Cement Mortars with 25% of selected Nano-silica a 16% increase in compressive strength was shown after 1day, reaching 63.9 MPa and after 28 days the strength was 95.9 MPa.

M. Sonebi et.al., (2015) The continuing use of various mineral additions along with chemical admixtures such as superplasticizers explains the need for extra research. Understanding and quantifying their effects and possible synergies on the fresh and hardened properties of cement-based materials is necessary, especially if some of these components are known to have a pozzolanic effect. This paper defines and models the fresh and hardened properties of cement mortars with Nano silica and fly ash, and relates their properties to the proportioning of these ingredients and the superplasticizer quantity. Mini-slump, Marsh cone and Lombardi cone tests were used to examine the properties of the fresh mortars, and to assess density, plastic shrinkage, and drying shrinkage up to 20 days. The equations presented in this paper make it possible to optimize mortar proportioning to the required levels of performance in both fresh and hardened states.

P. Di Maida et.al., (2015) investigated the effect of powdered and colloidal Nano-silica on the properties of cement mortar. Powdered Nano-silica used was with particle size of 40nm and colloidal silica used was of particle size 20 nm. The powder ns was synthesised using sol gel technique. SEM and XRD showed that the powder NS is amorphous in nature while colloidal is agglomerated in nature. In the study the compressive strength, CSH quantification and chloride diffusion. Approximately 27 and 37% enhancement in the compressive strength was observed using Nano-silica while there was only 19 % increase in the compressive strength when powdered silica was used. On the base of hydration of cement, the gel cement ratio was determined and it increases with compressive strength.

Sakshi Gupta, (2015) predicted the compressive strength of concrete with partial replacement of cement with Nano-silica using triangular membership function. Author said that Nano-silica can add many benefits to the durability cementations materials. The main aim of the study is to optimize the contents and reduce the cost and efforts by predefining suitable range of Nano-silica and it can be used to reduce the amount of cement used in the mix. Fuzzy logic was found useful in the prediction of compressive strength of concrete. So, it can be a useful tool for engineers and scientist in construction area without conducting experimental study in very short span of time and little margin for error.

Pengkun Hou et.al., (2014) studied the influence of two different types of Nano-silica in self compacting concrete. The two different Nano-silica were having same particle size distribution but manufactured from different processes i.e. fumed powder silica and colloidal silica. Both fresh as well as hardened properties were investigated. Also, microstructure was studies.

R. Yu et.al., (2014) studied the effect of Nano-silica on Ultra- High-Performance Fibre Reinforced Concrete with waste bottom ash. The main aim was to develop a design with densely compacted matrix. In the analysis flexural strength, compressive strengths, porosity and workability was studied. From the results the existence of the metallic aluminium particles was revealed and due to the generation of hydrogen macro cracks in the concrete were visible resulting in the reduced mechanical properties of concrete. With the use of Nano-silica the negative effect from Waste Bottom Ash.

L.P. Singh et.al., (2013) presented review on the effects on 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 rely.

Maheswaran et.al., (2013) author presents a critical review of the literature on the influence of Nano silica in concrete and its application for the development of sustainable materials in the construction industry and to study the pore filling effect and its pozzolanic activity with cement towards improvement of mechanical properties and durability aspects. Thus, there is a opportunity for progress of crack free concrete in the direction of workable construction.

Sayed et.al., (2013) Nano-silica particles with 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 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.

L. Senffa et.al., (2012) investigated cement mortars by adding Nano-SiO2 and Nano TiO2 with 0-3 percent by weight of cement of Nano-silica and 0-12 percent by weight of cement of Nano TiO2. Researches also determined the temperature and strength properties at 28 days. A considerable difference in rheological behaviour was validated. The addition of Nano particles reduced the open testing time and the values of torque, viscosity and yield stress was increased.

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 10nm size and the class F fly ash was used. Also experiments for the fresh and hardened properties of cement were conducted. Results obtained showed that the colloidal Nano-silica decreases the setting time of cement with fly ash.

G. Quercia et.al., (2011) compared and analysed 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 super plasticizers. 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 specimen with Nano-silica was bigger than cement.

Meral et.al., (2011) studied the combined as well as individual effect of three Nano particles namely Nano SiO2, Nano Al2O3 and Nano Fe2O3on the permeability and compressive strength of cement mixes containing silica fumes. The percentage used was 0.5%, 1.25% and 2.5% by weight of cement respectively. Compressive strength was calculated at 3 days, 7 days, 28 days, 56 days and 180 days.

V. Ershadi et.al., (2011) studied the effect of Nano-silica on permeability of oil well. As the Nano-silica is very fine in nature so it has been used to improve permeability and physical properties of the hardened material. With the addition of Nano-silica with very fine particles in the matrix the permeability was considerably reduced and the compressive strength was increased from 1486 psi to 3801 psi. various percentages were used to study the effect and the authors concluded that out of all the specimen with 1% Nano-silica is the most adequate.

Alireza Naji Givi et.al., (2010) studied the size influence of Nano SiO2 on mechanical and chemical properties of binary blended concrete the researchers used basically two types of Nano-silica 15 nm and 80 nm. A partial replacement of cement with different percentages of Nano-silica by weight was done. Authors concluded that at initial curing the samples with 15nm particles were comparatively harder than that with 80 nm but after 90 days of curing.

G. Quercia et.al., (2010) studied the application of Nano-silica in concrete mixtures. They concentrated on the reduction of cement content in the mixes because the cement is being used in pretty heavy quantity all over the world and the cement emits CO2 due to increased usage CO2 emission is also increased resulting in greenhouse effect. Authors also studied the suitability of the Nano silica in concrete Although Nano-silica can improve the chemical and physical properties of cement still it is not being used in the manufacturing industry because its production is complex and it comes on a great cost.

Belkowitz, (2009) investigated the effect on hydration process of cement by adding Nano-silica. Colloidal silica combines with the Calcium Hydroxide to enhance the strength of the cement. The new structure formed is calcium silica hydrate. Authors concluded that by addition of Nano-silica in the cement mortar many properties of cement begin to improve because the silica decreases in size and increase in size distribution.

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 w/c ratio (0.35-0.59). 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 study the specific samples with more restricted interval for 0.35 Water content the porosity and absorption had maximum values for 7% Nano-silica.

Ji Tao, (2005) the study was additionally done on the water porosity resistant behaviour and micro structure of concrete with Nano silica and ascertained that Nano Silica concrete includes a higher resistance permeability than normal concrete.

3. CONCLUSION

Nano silica make adverse effect when added in cement mortar with cement replacement in mechanical properties, durability properties and shrinkage properties.

1. Workability of cement mortar is decrease by increase in amount of Nano silica resulting from increase in rate of hydration process of cement with water.
2. Compressive strength, split tensile strength and flexural strength is increase with increase in amount of Nano silica in cement mortar.
3. Nano silica increase the density of cement mortar which results less pores in cement mortar.
4. Flowability of cement mortar is reduce by increase in amount of Nano silica. So, to maintain it super plasticizers in high amount is required.
5. Vacuum curing method is more effective then water curing up to 28 days. After, that water curing is more affective then vacuum curing.
6. Setting time is decrease with increase in amount of Nano silica in cement mortar.

REFERENCES

[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 flow ability, 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. Khatib3, 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 fibres 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] 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.*

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

[9] 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.*

[10] 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.*

[11] 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.*

[12] 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.*

[13] 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, *elsesiver-composites, 45, 2013, 440-448.*

[14] 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, 2012, 344–357.*

[15] 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.*

[16] 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.*

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

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

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

[20] 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.*

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