International Research Journal of

APPLIED SCIENCES

Volume 01 | Issue 01 | 2019

SciRange
PUBLICATIONS
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SciRange Open Access

International Research Journal of Applied Sciences Research Article

pISSN: 2663-5577, eISSN: 2663-5585

The Effect of Nano Silica on Mechanical Properties of Concrete

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ARTICLE INFORMATION

Received: October 25, 2018

Accepted: November 13, 2018

Published: January 31, 2019

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ABSTRACT

The numerous explorative works have been done since two decades by utilizing Nano materials, such as Nano silica, Nano alumina etc., to accomplish a high strength and to increase the durability of concrete. In the principle of environmental sustainability, fly ash is used for fractional substitution of cement. The present work concentrates principally towards the addition of Nano silica particles in colloidal form with the reference concrete mix. The cement was replaced with fly ash at [illegible], 20 and 25% in concrete mixture. In addition to this 1 and 2% of Nano silica was used in concrete to enhance the fresh and hardened properties of concrete. Various tests were conducted in order to obtain the compressive strength, split tensile strength and flexural strength of the improved concrete. Results showed the incorporation of the Nano silica in concrete increases the mechanical properties of concrete and the mix with combination of 25% fly ash and 1%XTXla type Nano silica had shown the highest strength characteristics when compared to all other mixes.

Key words: Nano materials, Nano silica (nS), compressive strength, split tensile strength, flexural strength

INTRODUCTION

The construction industries are presenting numerous new and propelled materials for the development of structures. Cement is one of the commodities used in large quantities for the structures, yet increasing the cement production leads to environmental pollution[1]. The essential strategy is to reduce the cement quantity in concrete, to replace cement with other materials having pozzolanic nature such as silica fume or micro silica and Nano silica, thereby reducing pollution of environment[2-4]. The use of nS and its impact in concrete is not yet completely analysed. This study intends to display the significance of nS applications in cement concrete and to concentrate on the nS properties to render the appropriateness in concrete[5,6]. Only very few studies has been carried out on the usage of Nano silica and fly ash in concrete. Many research works were carried out using Nano materials but the works on combination of fly ash and Nano materials are very less[7].

Calcium silicate hydrate formed by good pozzolanic nature of silica fume reacts with Ca $(OH)_2$. Stronger concrete with minimum pores can be achieved by the hydrate present of silica fume is 25 $m^2 g^{-1}$, which is 80 times more than ordinary Portland cement. The size of Nano silica particles which is lesser than silica fume increases the surface area and reduces the pores giving a stronger mix of concrete. There is no much considerable effect on the characteristics of cement by the blending of cement and silica fume. Water absorption and compressive strength test were conducted using the Nano silica prepared by sol-gel method[9,10]. Agglomerates of silica particles developed from pyrogenic silica powder are less than colloidal Nano silica, this act as filler and helps more effectively in developing Calcium silicate hydrate gel. At initial days, colloidal form of Nano silica in concrete gives more compressive strength than powder form of Nano silica, but on later ages both colloidal as well as powder Nano silica will give equal strength[11,12].

Fly ash plays an important role in reducing the pollution caused due to cement production. Strength of mortar can be enhanced by adding Nano silica and fly ash by high temperature curing[13-15]. Analysis made for effective dispersion of Nano particles in concrete mixes states that it will give better mechanical and durable strength resulting in high strength concrete[16,17]. This study mainly focused on the development of M30 blended concrete using fly ash and Nano silica.

MATERIALS AND METHODS

Cement: In the present investigation, 53 Grade of Cement Ordinary Portland Cement satisfying requirements as per IS 12269: 2013 was used for all concrete mixes; its trade name is Zurai Cements Pvt Ltd.

Fly ash: The most widely used supplementary cementations material in concrete, is a byproduct of the combustion of pulverized coal in electric power generating plants. During combustion, the coal's mineral impurities (such as clay, feldspar, quartz, and shale) fuse in suspension and are carried away from the combustion chamber by the exhaust gases. In the process, the fused material cools and solidifies into spherical glassy particles called Fly ash.

Coarse aggregate: Natural rounded uncrushed gravel was used as the coarse aggregate in this investigation. It passed through a 20 mm sieve whereas was retained on a 16 mm sieve.

Fine aggregate: Locally available river-bed sand was used as the fine aggregate in this investigation.

Table 1: Mix proportion for M30 grade of concrete

Materials	Cement	Fine aggregate	Coarse aggregate	Water
	($kg\ m^{-3}$)			
Quantity	350.2	721.5	1273.8	150.5

Mix proportion =1: 2.06: 3.63 with water cement ratio (w/c) of 0.43

Nano silica: Four different types of colloidal Nano silica's namely XFX with crystalline size of 10-50 NM, XTXla with crystalline size of 10-30 NM, XTX with crystalline size of 20-50 NM, XLP with crystalline size of 40-50 NM) manufactured by Beechems Chemical manufacturer were used in this investigation.

Water: Tap water available in the university campus was used in this investigation for the purpose of preparing the mixes.

Mix design and methods: The M30 Grade of concrete mix design was arrived at according to IS 10262-2009. The mix proportions used at for the experiments are shown in Table 1.

Mix preparation: For the purpose of mixing the materials, tools like trowels and horizontal pans were employed. Ordinary Portland Cement, Fly ash, coarse aggregate and fine aggregate were all dry-mixed in the first step. This process was carried out for about 30 sec; after that, water and colloidal nano silica was added to the mix to form the concrete mixes.

Casting and curing of moulds: After mixing was accomplished, concrete was placed in pre-oiled cube moulds of dimension 100×100×100 mm, Cylinder moulds of 200×100 mm and beam size of 500×100×100 mm. After allowing the specimens under dry conditions for 24 h, they were immersed in water for the purpose of curing for a period of 7, 14 and 28 days as may be applicable to the individual cases.

RESULTS AND DISCUSSION

Compressive strength: The specimens were subjected to compression test on the Compression Testing Machine (CTM).This part of the research work was performed in two phases.

Phase I-Selection of optimum percentage of Fly ash: Phase I describes the investigation carried out to evaluate the compressive strength of concrete into different percentages of fly ash as a partial replacement of cement to find the optimum percentage of fly ash replacement (M1). The results are graphically illustrated in Fig. 1.

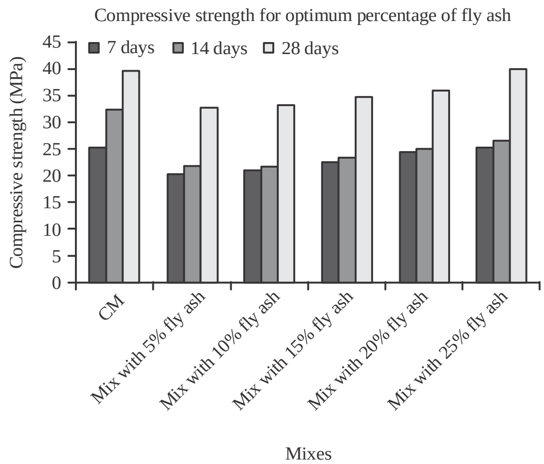

Fig. 1: Graphical representation of selection of optimum percentage of fly ash at different ages

The mix with 25% Fly ash replacement of cement has shown the maximum strength. Hence, it was concluded that the optimum percentage of replacement of cement by Fly ash could be taken as 25%.

Phase II - Compressive strength of concrete with Fly ash-Nano silica combination: Phase II deals with the investigation carried out for the evaluation of the compressive strength of the mixes with nano silica content 1 and 2% with the mix notations as M2-1% XFX, M3-1% XTXla, M4-1% XTX, M5-1% XLP, M6-2% XFX, M7-2% XTXla, M8-2% XTX to M9-2% XLP. The experimental results are depicted in Fig. 2.

The compressive strength of all types of nano silica concrete cubes with constant 25% of Fly ash replacement for cement is shown in Fig. 2. The compressive strength of all types of nano silica mixes was higher than the conventional concrete. The compressive strength of all concrete mixes increased with age. From the result, it is clearly seen that blended concrete mix containing 1% XTXla Nano silica has developed higher strength than that of other blended concrete mixes. The rapid development of the strength of blended concrete with Nano silica shows that it not only serves as a filler to increase the density of the nano structure of concrete, but also serves as an activator in hydration process[2]. The inclusion of Nano silica enhanced the compressive strength for all the employed cases, in comparison with the conventional control[15].

Split tensile strength test: Split tensile strength test was performed on mixes M2 to M9. The experimental results are depicted in Fig. 3.

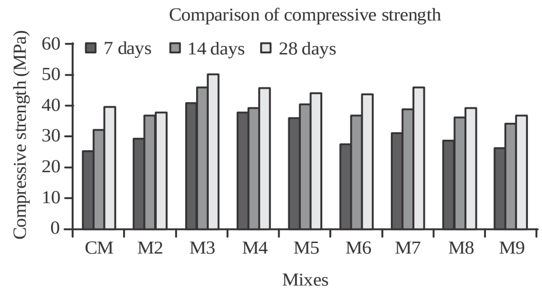

Fig. 2: Graphical representation of compressive strength of concrete at different ages

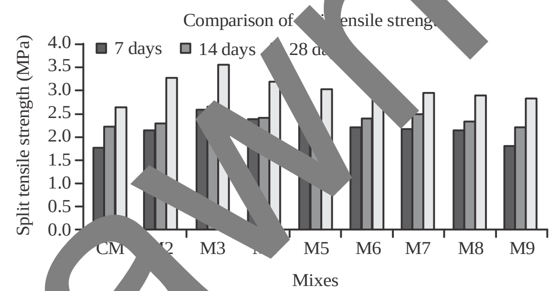

Fig. 3: Graphical representation of split tensile strength of concrete at different ages

The split tensile strength of all types of nano silica concrete cubes with constant 25% of Fly ash replacement for cement is shown in Fig. 3. The split tensile strength of all types of nano silica mixes was higher than the conventional concrete. The split tensile strength of all concrete mixes increased with age. From the result, it is clearly seen that blended concrete mix containing 1% XTXla Nano silica has developed higher strength than that of other blended concrete mixes. Due to an increase in particle packing and a reduction of unfavorable crystals (e.g., $Ca(OH)_2$ and ettringite) dimensions have direct effects on improving ITZ strength, the fourfold performance of well-dispersed nano-SiO_2 particles can develop ITZ and consequently significantly increase the splitting tensile strength in comparison with the compressive strength[14,18]. The denser ITZ did not necessarily result in the highest compressive strength but the improvement of the ITZ can affect tensile strength and even durability[16].

Flexural strength test: Test for Flexural strength of the mixes M2 to M9 were performed in Universal Testing Machine (UTM). The experimental results are depicted in Fig. 4.

The effect of using nano silica on flexure strength is presented in Fig. 4. The flexural strength of all types of nano silica mixes was higher than the conventional concrete. The flexural strength of all concrete mixes increased with age. From the

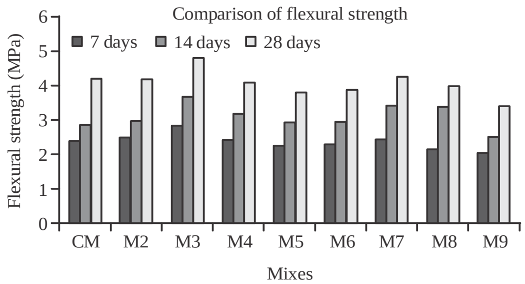

Fig. 4: Graphical representation of flexural strength of concrete at different ages

result, it is clearly seen that blended concrete mix containing 1% XTXla Nano silica has developed higher strength than that of other blended concrete mixes. This improvement can be referred to the filler action of nano silica which had a higher surface area which improves the chemical reaction due to the pozzolanic activity, additional Calcium Silicate Hydrates are formed to generate more strength and to reduce free calcium hydroxide[19-25]. A similar trend was observed in compressive and split tensile strength.

CONCLUSION

It was observed that in concrete, having combination of Fly ash and Nano silica sets quickly than that of control concrete. The results of compression tests with Fly ash and Nano silica combinations at different ages show that the values are superior compared to control concrete. In this investigation, the highest compression strength was achieved by the combination of FA-XTXla type Nano silica at 25-1% respectively, also it gave maximum strength values in split tensile and flexural strength. Addition of replacement materials leads to eco-friendly and sustainable concrete and at the same time results in the reduction of overall cost of manufacture of concrete.

REFERENCES

1. Ji, T., 2005. Preliminary study on the water permeability and microstructure of concrete incorporating nano-SiO_2. Cement Concrete Res., 35: 1943-1947.
2. Byung-Wan, J., K. Chang-Hyun, T. Ghi-ho and P. Jang-Bin, 2007. Characteristics of cement mortar with nano-SiO_2 particles. Constr. Build. Mater., 21: 1351-1355.
3. Nilli, M., A. Ehsani and K. Shabani, 2009. Influence of nano SiO_2 and micro silics on concrete performance. Bu-Ali Sina University Iran.
4. Nazari, A., S. Riahi, S. Riahi, S. Fatemeh Shamekhi and A. Khademno, 2010. Embedded ZrO_2 nanoparticles mechanical properties monitoring in cementitious composites. J. Am. Sci., 6: 86-89.
5. Nazari, A., S. Riahi, S. Riahi, S. Fatemeh Shamekhi and A. Khademno, 2010. Improvement of the mechanical properties of the cementitious composites by using TiO_2 nanoparticles. J. Am. Sci., 6: 98-101.
6. Nazari, A., S. Riahi, S. Riahi, S. Fatemeh Shamekhi and A. Khademno, 2010. Mechanical properties of cement mortar with Al_2O_3 nanoparticles. J. Am. Sci., 6: 94-97.
7. Givi, A.N., S.A. Rashid, F.Nora A. Aziz and M.A. Mohd Salleh, 2010. Experimental investigation of the size effects of SiO_2 nano particles on the mechanical properties of binary blended concrete. Composites, B, 41: 673-677.
8. Quercia, G. and H.J.H. Brouwers, 2010. Application of nanosilica (nS) in concrete mixtures. The 8th fib PhD symposium in Kgs. Lyngby, Denmark.
9. Morsy, M.S., S.H. Alsayed and M. Aqel, 2010. Effect of Nano clay on mechanical properties and microstructure of Ordinary Portland Cement mortar. Int. J. Civil Eng. Environ. Eng., 10: 01.
10. Shekari, A.H. and M.S. Razzaghi, 2011. Influence of nanoparticles on durability and mechanical properties of SCC with GGBFS as binder. Energy Build., 43: 995-1002.
11. Givi, A.N. and S.A. Rashid, 2011. The effect of lime solution on the properties of SiO_2 nanoparticles binary blended concrete. Composites (Part B)., 42: 562-569.
12. Navneet, C. and R. Siddique, 2012. Influence of bacteria on the compressive strength, water absorption and rapid chloride permeabilty of concrete incorporating siloca fume. Constr. Build. Mater., 37: 645-651.
13. Said, A.M., M.S. Zeidan, M.T. Bassuomi and Y. Tian, 2012. Properties of concrete incorporating nano-silica. Constr. Build. Mater., 36: 838-844.
14. Heidari, A. and D. Tavakoli, 2012. A study of mechanical properties on ground ceramic powder concrete incorporating nano SiO_2 particles. Constr. Build. Mater., 38: 255-264.
15. Chahal, N. and R. Siddique, 2013. Permeation properties of concrete made with fly ash and silica fume: Influence of ureolytic bacteria. Constr. Build. Mater., 49: 161-174.
16. Shakir, A. Al-Mishhamid, A.M. Ibraham and Z.H. Naji, 2013. The effect of nano metakaolin materials on some properties of concrete. Diyala J. Eng. Sci., 6: 50-61.
17. Dhinakaran, G., A. Rajasekharareddy, B. Kartikeyan, K. Sumanth and G. Harshavardhan, 2014. Microstructure analysis and strength properties of concrete with Nano SiO_2. Int. J. ChemTech. Res., 6: 3004-3013.
18. Quercia, G., P. Spiesz, G. Hüsken and H.J.H. Brouwers, 2014. SCC modification by the use of amorphous nano-silica. Cem. Concr. Compos., 45: 69-81.
19. Atmaca, N., M.L. Abbas and A. Atmaca, 2017. Effects of nano-silica on the gas permeability, durability and mechanical properties of high-strength lightweight concrete. Constr. Build. Mater., 147: 17-26.
20. HajizadehAsl, D., 2016. Application of Nano-Silica in Concrete to Improve its Mechanical Properties and Durability: A Review. Int. J. Recent Sci. Res., 7: 12251-12254.

21. Narender, R.A. and T. Meena, 2018. Study on effect of colloidal Nano silica blended concrete under compression. Int. J. Eng. Technol., 7: 210-213.
22. Narender, R.A. and T. Meena, 2017. Behaviour of Ternary Blended Concrete under Compression. Int. J. Civil Eng. Technol., 8: 2089-2097.
23. Narender, R.A. and T. Meena, 2017. A Comprehensive Overview on Performance of Nano Silica Concrete. Int. J. Pharm. Technol., 9: 5518-5529.
24. Narender, R.A. and T. Meena, 2017. An Experimental Investigation on Mechanical Behaviour of Eco-Friendly Concrete. 14th ICSET-2017, 263: 032010.
25. Narender, R.A. and T. Meena, 2018. A Study on Compressive Behavior of Ternary Blended Concrete. Materials Today: Proceedings, 5: 11356-11363.