GAVIN PUBLISHERS

# Nanomedicine and Nanoscience Research

Mohammed BS, et al. J Nanomed Nanosci: JNAN-128.

DOI: 10.29011/JNAN-128.100028

Short Commentary

# A Review on Nano-Silica Based Concrete

**Bashar S Mohammed*, Veerendrakumar C Khed, Muhd Fadhil Nuruddin**

Universiti Teknologi PETRONAS, Malaysia

***Corresponding author:** Mohammed BS, Department of Civil and Environmental Engineering, Universiti Teknologi PETRONAS, 32610 Bandar Seri Iskandar, Perak Darul Ridzuan, Malaysia. Tel: +6053687305; Email: bashar.mohammed@utp.edu.my

Citation: Mohammed BS, Khed VC, Nuruddin MF (2017) A Review on Nano-Silica Based Concrete. J Nanomed Nanosci: JNAN-128. DOI: 10.29011/JNAN-128.100028

**Received Date:** 16 October, 2017; **Accepted Date:** 31 October, 2017; **Published Date:** 07 November, 2017

## Abstract

Nanomaterials are being used in concrete technology to enhance the performance and sustainability of the construction materials. In most of the previous studies, nano-silica was used as an additive for the cementitious material. It was depicted that nano-silica improves the mechanical and durability properties due to its physico-chemical reactive characteristics. Contrarily the addition of nano-silica reduces the workability of concrete and that can be diminished through adjusting the superplasticizer by maintaining the optimum quantity of water.

**Keywords:** Calcium-Silicate-Hydrate(C-S-H) gel; Physico Chemical Effect; Nano Silica; Nanotechnology

## Introduction

Concrete is one of the essential construction material due to its significant features such as the ability to mold for any shapes, low cost and high strength, most of the ingredients are naturally available despite its concern with the environment. In the world, around 8% of carbon dioxide emitted due to the production of cement [1] which can be used to produce 20 billion metric ton of concrete approximately [2]. This huge percentage of carbon dioxide emission has become an issue of environmental concern. Day to day new ideas are being established in the construction industry in order to maintain the environmental sustainability [3]. Concrete is a composite material which comprises of the materials in a range of micrometer to the millimeter. Generally, concrete is considered to be a single unit for its fresh and hardened engineering properties, then again at micro and Nano level, it has complex characteristics along with different compositions. There has been a correlation between the strength properties and microstructure of concrete, which created the interest for the researchers in establishing the relationship. Contemporarily the construction sector is functioning on the development of the new and advanced cementitious material. Proper utilization of the materials in the cementitious system helps in enhancing the strength, durability, sustainability and also cost-effective in terms of maintenance.

On the other side, in science and technology, nanotechnology has been developing to be an advanced science for the future. Nano-engineered materials proven to be better performance than their higher sized materials [4]. According to Drexler et al. [5] nanotechnology can be defined as "In a matter, control of the structure based on the molecule products and its by-products". Some of the researchers defined the nanotechnology that "The understanding, manufacturing, and control of the matter into the nanometers in creating the materials for the modern properties and functions" [6]. In concrete science the term nanotechnology may be defined as the bulk properties of the concrete can be altered by controlling the material properties at the nanometer scale. The importance of nano-silica in concrete technology has been graphically elaborated in (Figure 1).

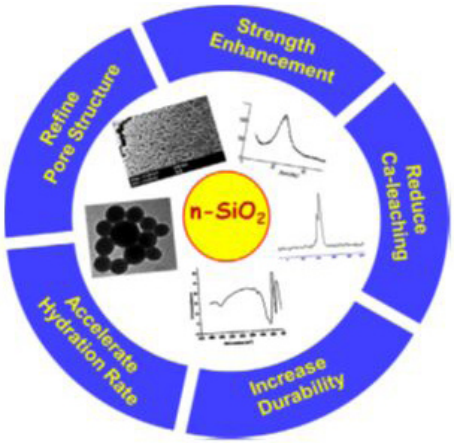


**Figure 1:** Importance of Nano silica in concrete technology [7,8].

By using the ultrafine substances like nano-silica as an additive in the cement based products improves the properties of hardened concrete. Both physical and chemical effects due to the

addition of nano-silica play role in producing the high-performance concrete [9]. Physically nanoparticles have the ability to fill the voids between the cement particles. Best composition of materials can produce high packing density resulting in low water demand leading towards the enhancement of strength due to its reduced porosity. Chemically nano-silica addition increases the pozzolanic reactivity when compared with the silica fume. Besides this, the hydration of cement can be speeded by the addition of nano-silica. The nano-silica in the cementitious matrix create additional C-S-H gel by the formation of reaction between $H_2SiO^{2-}_4$ and $Ca^{2+}$, thus the C-S-H gel spread between the cement particle leading towards better compaction of cement particles. This additional C-S-H gel accelerates the hydration of cement [9].

In this work, the previous researches on fresh and mechanical properties of Nano-silica, which was added in percentage of cementitious material on various types of concrete have been reviewed and the conclusion remarks were drawn.

## Fresh Properties

Nano silica in concrete absorbs some part of mixing water because of its high reactivity and the high specific area which induces the reduction in workability. To increase the workability superplasticizer was added [10]. The addition of nano-silica in concrete reduces the bleeding and segregation and helps in increasing the cohesiveness of concrete. Nano silica addition requires more water to maintain its workability [11]. The addition of nano-silica in Engineered Cementitious Composite (ECC) demanded a higher percentage of superplasticiser to retain the optimum amount of water for the required workability [12]. One of the study says that nano-silica effect on the cement paste induces an instantaneous reaction between the liquid segment of cementitious and the nano-silica to form the gel with a high retention of water capacity [13]. In a self-compacting mortar, increased quantity of Nano-silica reduced the slump value [14]. In most of the studies confirm that the mineral particles having high surface area prone to the low workability that led to the higher quantity of water and admixture requirement.

## Mechanical Properties

Mohammed et al studied the compression strength of rubberized concrete by varying the nano-silica addition up to 5% and it was observed that compressive strength increased gradually due to the physico-chemical effect of nano-silica which filled the micropores of the rubberized concrete as shown in (Figure 2 (a)) [4]. In a combination with fly ash, the addition of nano-silica helps in increasing the early strength of concrete as shown in (Figure 2(b)) [10,15,16]. The C-S-H gel formation due to the pozzolanic reaction was quicker and faster when the addition of nano-silica in the cement paste, this led to the improvement in the compressive strength and flexural strength [9, 17,18]. The Nano-silica addition increased the bending strength, tensile strength, abrasion strength [19]. Nanosilica in fiber-phenolic composite, the bending strength increased by 13% up to the addition of 3% of nano-silica and decreased for 5% addition of Nano silica [20]. Addition of nano-silica improves the Interfacial Transition Zone (ITZ) property which further helps in improvement of compression strength, flexural strength, and modulus of elasticity [21]. In rubberized roller compacted concrete, the loss of strength due to crumb rubber was mitigated by the addition of Nano-silica [22]. In sawdust-crete, sawdust particles were pre-coated by Nano-silica, which improved the compression strength by reducing the MIP (mercury intrusion porosimetry) and ITZ [23]{Mohammed, 2016 #138}. Sodium silicate demand was reduced due to the addition of nanosilica [24]. The addition of Nano-silica up to 4% had resulted in an increase in the compression strength of ECC gradually and beyond 4% it was decreased [25]. Up to 15 MPa strength of solid bricks can be produced by utilizing Nano-silica in rubberized concrete [26].

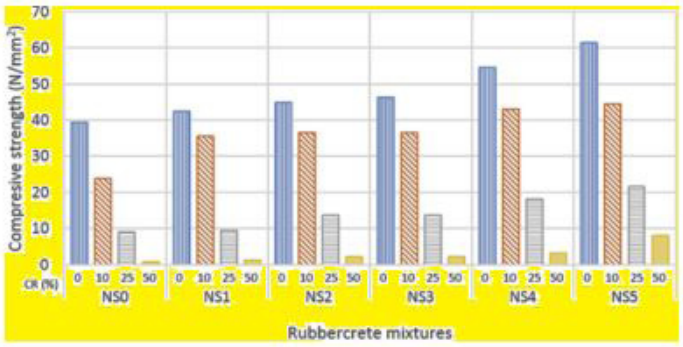


**Figure 2(a):** Effect of compression strength of nano-silica in combination with crumb rubber concrete [4].

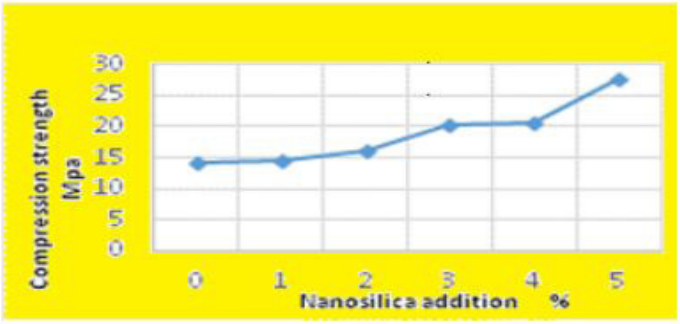


**Figure 2(b):** Effect of compression strength of nano-silica in self-compacting mortar.

**Figure 2:** Effect of nano-silica on compression strength of rubberized concrete.

## Durability Properties

The durability in terms of sulphuric acid attack was investigated and compared with micro and nano-silica, it was found that the effect of inclusion of 7% of micro silica was equivalent 2% of

Nano silica [27]. In sugarcane bagasse, ash mortar with nano-silica improved durability performance in terms of chloride ingress, better electrical resistivity, improved pore structure [28]. Nano silica played a better role in the reduction of water absorption and chloride penetration [29]. The addition of Nano-silica reduced the thermal conductivity and sorptivity [30]. The extension of cracks was prevented when exposed to the elevated temperature due to the inclusion of nano-silica [31]. Nano-silica enhanced the corrosion resistance due to its binding nature with Ca(OH)2 in Portland cement [32]. A significant reduction in plastic shrinkage was observed for the Nano-silica based cement mortar [33].

## Conclusion and Remarks

Using nanomaterial such as nano-silica in concrete improves the hardened properties, durability characteristics and contrarily reduces the workability which can be adjusted by adding the superplasticizer. Thus, by using nanotechnology in the construction industry can produce high-performance concrete for the future engineering structures. Hence the nanotechnology proved to be an advanced technology in the concrete domain.

## Future scope

Maximum researchers worked on nano-silica have been limited to the fresh and mechanical properties of conventional concrete. More research needs to work on other types of concrete such as geopolymer, ECC, rubbercrete. Furthermore, research to be carried out on dynamic and durability properties of Nano-silica modified concrete. In addition to Nano-silica, nanotechnology can be extended for various other nano-materials.

## References

1. Olivier JG, Maenhout GJ, Muntean M, Peters J (2012) Trends in global CO2 emissions; 2012 Report, The Hague: PBL Netherlands Environmental Assessment Agency. Joint Research Centre, Ispra.
2. Mehta PK and Meryman H (2009) Tools for reducing carbon emissions due to cement consumption. Structure 1: 11-15.
3. Mohammed BS, Khed VC, Nuruddin MF (2017) Rubbercrete Mixture Optimization Using Response Surface Methodology. Journal of Cleaner Production.
4. Mohammed BS, Awang AB, Wong SS, Nhavene CP (2016) Properties of nano silica modified rubbercrete. Journal of Cleaner Production 119: 66-75.
5. Drexler KE, Peterson C, Pergamit G (1991) Unbounding the future," William Morrow, New York, p. 294, 1991.
6. Rupasinghe M, Mendis P, Gammampila R, Ngo T (2013) Nanoengineering concrete for sustainable built environment: a review.
7. Singh L, Karade S, Bhattacharyya S, Yousuf M, Ahalawat S (2013) Beneficial role of nanosilica in cement based materialsA review. Construction and Building Materials. 47: 1069-1077.
8. Adamu M, Mohammed BS, Shafiq N (2016) Nano silica modified roller compacted rubbercretean overview. in Engineering Challenges for Sustainable Future: Proceedings of the 3rd International Conference on Civil, Offshore and Environmental Engineering (ICCOEE 2016, Malaysia, 15-17 August 2016 pg no: 483.
9. Zapata L, Portela G, Suárez O, Carrasquillo O (2013) Rheological performance and compressive strength of superplasticized cementitious mixtures with micro/nano-$SiO_2$ additions. Construction and Building Materials 41: 708-716.
10. Veerendrakumar C, Nuruddin M, Mohammad B (2016) Effects of Nano silica modified self-compacted, high volume fly ash mortar on slump flow and compressive strength. Madridge J Nano Tec. Sci 1: 2016.
11. Jalal M, Mansouri E, Sharifipour M, Pouladkhan AR (2012) Mechanical, rheological, durability and microstructural properties of high performance self-compacting concrete containing $SiO_2$ micro and nanoparticles. Materials & Design. 34: 389-400.
12. Mohammed BS, Achara BE, Nuruddin MF, Yaw M, Zulkefli MZ (2017) Properties of Nano-silica-modified self-compacting engineered cementitious composites. Journal of Cleaner Production. 62: 1225-1238.
13. Berra M, Carassiti F, Mangialardi T, Paolini A, Sebastiani M (2012) Effects of Nano silica addition on workability and compressive strength of Portland cement pastes. Construction and Building Materials 35: 666-675.
14. Achara BE, Mohammed BS, Nuruddin MF (2013) Optimisation of nano-silica modified self-compacting high-Volume fly ash mortar. in IOP Conference Series: Materials Science and Engineering 201: 01
15. Aleem SAE, Heikal M, Morsi W (2014) Hydration characteristic, thermal expansion and microstructure of cement containing nano-silica. Construction and Building Materials 59: 151-160.
16. Nili M and Ehsani A (2015) Investigating the effect of the cement paste and transition zone on strength development of concrete containing Nano silica and silica fume. Materials & Design 75: 174-183.
17. Guefrech A, Mounanga P, Khelidj A (2011) Experimental study of the effect of addition of nano-silica on the behaviour of cement mortars Mounir. Procedia Engineering 10: 900-905.
18. Qing Y, Zenan Z, Deyu K, Rongshen C (2007) Influence of Nano $SiO_2$ addition on properties of hardened cement paste as compared with silica fume. Construction and building materials 21: 539-545.
19. Riahi S and Nazari A (2011) Compressive strength and abrasion resistance of concrete containing $SiO_2$ and CuO nanoparticles in different curing media. Science China Technological Sciences 54: 2349-2357.
20. Mirzapour A, Asadollahi MH, Baghshaei S, Akbari M (2014) Effect of Nano silica on the microstructure, thermal properties and bending strength of Nano silica modified carbon fibre/phenolic nanocomposite. Composites Part A: Applied Science and Manufacturing 63: 159-167.
21. Xu J, Wang B, Zuo J (2017) Modification effects of Nano silica on the interfacial transition zone in concrete: A multiscale approach. Cement and Concrete Composites 81: 1-10.
22. Adamu M, Mohammed BS, Shafiq N (2017) Flexural performance of Nano silica modified roller compacted rubbercrete. International Journal of Advanced and Applied Sciences 4: 6-18.

23. Mohammed BS, Nuruddin M, Ishak N (2016) Hardened properties of sawdust-crete containing pre-coated sawdust with nano-silica. in Advances in Civil, Architectural, Structural and Constructional Engineering: Proceedings of the International Conference on Civil, Architectural, Structural and Constructional Engineering, Dong-A University, Busan, South Korea, August 21-23, 2015 pg no: 3.

24. Zamorano LG, Cordero EV, Struble L (2016) Composite geopolymers of metakaolin and geothermal nanosilica waste. Construction and Building Materials 115: 269-276.

25. Mohammed BS, Syed ZI, Khed V, Qasim MS (2017) Evaluation of Nano-Silica Modified ECC Based on Ultrasonic Pulse Velocity and Rebound Hammer. The Open Civil Engineering Journal 11:

26. Mahamood N, Mohammed B, Shafiq N, Eisa S (2016) Development of Nano silica modified solid rubbercrete bricks. in Engineering Challenges for Sustainable Future: Proceedings of the 3rd International Conference on Civil, Offshore and Environmental Engineering (ICCOEE 2016, Malaysia, 15-17 Aug 2016 pg no: 443

27. Hendi A, Rahmani H, Mostofinejad D, Tavakolinia A, Khosravi M (2017) Simultaneous effects of microsilica and nanosilica on self-consolidating concrete in a sulfuric acid medium. Construction and Building Materials 152: 192-205.

28. Joshaghani A and Moeini MA (2017) Evaluating the effects of sugar cane bagasse ash (SCBA) and nanosilica on the mechanical and durability properties of mortar. Construction and Building Materials 152: 818-83.

29. Beigi MH, Berenjian J, Omran OL, Nik AS, Nikbin IM (2013) An experimental survey on combined effects of fibers and nanosilica on the mechanical, rheological, and durability properties of self-compacting concrete. Materials & Design 50: 1019-1029.

30. Sikora P, Horszczaruk E, Skoczylas K, Rucinska T (2017) Thermal Properties of Cement Mortars Containing Waste Glass Aggregate and Nanosilica. Procedia Engineering 196: 159-166.

31. Horszczaruk E, Sikora P, Cendrowski K, Mijowska E (2017) The effect of elevated temperature on the properties of cement mortars containing nanosilica and heavyweight aggregates. Construction and Building Materials 137: 420-431.

32. Larisa U, Solbon L, Sergei B (2017) Fiber-reinforced concrete with mineral fibers and Nano silica. Procedia Engineering 195: 147-154.

33. Sonebi M, Taengua EG, Hossain K, Khatib J, Lachemi M (2015) Effect of nanosilica addition on the fresh properties and shrinkage of mortars with fly ash and superplasticizer. Construction and Building Materials 84: 269-276.