International Journal Of
Recent Scientific Research
ISSN: 0976-3031
Volume: 7(6) June -2016

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DariushHajizadehAsl

THE OFFICIAL PUBLICATION OF
INTERNATIONAL JOURNAL OF RECENT SCIENTIFIC RESEARCH (IJRSR)
http://www.recentscientific.com/ recentscientific@gmail.com

ISSN: 0976-3031

Available Online at http://www.recentscientific.com

International Journal of Recent Scientific Research
Vol. 7, Issue, 6, pp. 12251-12254, June, 2016

International Journal of Recent Scientific Research

Review Article

APPLICATION OF NANO-SILICA IN CONCRETE TO IMPROVE ITS MECHANICAL PROPERTIES AND DURABILITY: A REVIEW

DariushHajizadehAsl

Department of Civil Engineering, Gorgan Branch, Islamic Azad University, Gorgan, Iran

ARTICLE INFO

Article History:

Received 05th March, 2016
Received in revised form 21st April, 2016
Accepted 06th May, 2016
Published online 28th June, 2016

Key Words:

Nano-silica, Concrete, Mechanical Properties, Durability.

ABSTRACT

One of the most important building materials in civil engineering projects is concrete, which is being extensively used all around the world. However, there concerns in the use of concrete in construction attempts regarding its mechanical properties and durability in different settings and environments. Therefore, there has been a great incentive to find out some ways to improve these properties in concretes. One of the most popular ways, at least in theoretical attempts, is the use of Nano-silica in production of concretes. There have been several studies on the application of this agent to improve different properties of concrete. The present study is a review on the use Nano-silica in production of concrete in order to improve its mechanical properties and durability.

INTRODUCTION

Concrete can be regarded as the most popular building material all around the world and its production is estimated to be one cubic meter per capita (Ibrahim & Ahmed, 2008).

Nano-science is very effective in production of new concretes in the present century. Nano-science is a branch of science that deals with atoms and molecules for production of novel materials, which possess more favorable properties. When a materialhas at least one componentsmaller than 100 nm, it can be called a Nano-material. In other words, '*a nanomaterial refers to a solid whose atomic arrangement, size of its crystals, and its chemical composition could be extended in a multi-nanometer scale*' (MohammadiAtashgah *et al*., 2014).

Reusing by products such as fly-ash, silica fume, and Nano-silica is very important in order to achieve sustainability goals in civil engineering. Performance and efficiency of concrete heavily relies on Nano size constituents such as Calcium Silicate Hydrates (C-S-H) particles. These additives are believed to increase durability and strength of concrete because they consist of fine particles, they have large surface area, and they have a high level of silica (Kuli *et al*., 2016). Nano-silica is preferred over other Nano-particles because it has a high capability of improving microstructure of cement-based products like concrete (Boshehrian&Hosseini, 2011). Table 1 summarized the characteristics of Nano-silica.

Table 1 Characteristics of Nano-silica (PrasadaRao & Navaneethamma, 2016)

Active Nano content (% wt/wt)	30-32
pH (at 20°C)	9-10
Specific gravity	1.20-1.22
Texture	White milky liquid
Dispersion	Water

Cement composites with Nano-silica are suitablein order to be used in several applications in which early compressive strength should be taken into account; these applications include concrete roof tiles, masonry blocks, and high strength mortars. They are also important for applications in which flexural strength should be greatly improved, notably in cases where unreinforced cement composites are adopted, for example airport concrete pavements and roads in order to distribute concentrated loads securely in extensive areas. However, special attention should be given to different factors before the application of Nano-silica in concrete applications; for instance,special evaluations should be executed in order to understand the influence of Nano-silica on the permeability, water absorption, workability, long term durability and creeping of concrete, as well as the manufacturing, safety and handling issues, among others (Biricik&Sarier, 2014).

Use of even small amount of Nano-silica can improve different properties of cement and concretes and therefore, it can be considered a very important material especially in civil engineering. Therefore, the present study aimed at presenting a

*Corresponding author: DariushHajizadehAsl
Department of Civil Engineering, Gorgan Branch, Islamic Azad University, Gorgan, Iran

review on the use of Nano-silica in production of concrete in civil engineering.

Effect of Nano-silica on mechanical properties of concrete

Khanzadi *et al*. (2010) determined the influence of adding Nano-silica into the concrete on mechanical properties. They concluded that addition of Nano-silica enhanced compressive and tensile strength of the concretes especially in the early parts of use. They also found that using Nano-silica could improve structures of cement paste. Also, they concluded that the concretes made by using Nano-silica have a better resistance against permeability because these particles provide a more uniform distribution in the structure of concretes.

Parida (2015) evaluated the effect of incorporation of Nano-silica on compressive strength of concrete and found that the concrete fortified by Nano-silica showed a very high level of compressive strength in the early ages although the strength decreases with time. Also, Jahangir and Kazemi (2014) showed that combination of 10 percent Nano-silica and 5% Nano-alumina in concrete improves compressive strength of the concrete at all stages of using concretes. They further indicated that using this combination is also helpful for reduction of concrete permeability.

In a study on compressive strength of concretes containing crumb rubber, Sohrabi and Karbalaei (2011) concluded that incorporation of Nano-silica in concretes containing rubber results elevates 7- and 28- day compressive strength compared to those concretes only with crumb rubber. These findings were justified by the fact that Nano materials can fill the Nano voids, which leads to a thicker structure. Moreover, TorabianIsfahani *et al*. (2016) found that addition of Nano-silica in concrete reduced the porosity in the microstructure of concrete whereby reduced permeability of the concretes (Fig. 1).

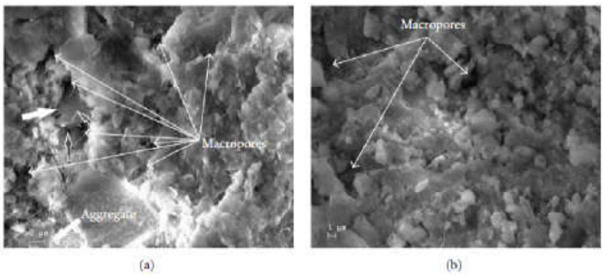

Figure 1 Reduction of porosity and therefore, permeability of concretes with Nano-silica; (a) concrete without Nano-silica; (b) concrete with Nano-silica (TorabianIsfahani *et al*., 2016)

Singh *et al*. (2015) compared the effect of two types of Nano-silica, i.e. powdered and colloidal (Fig. 2), on mechanical properties of concrete. They found that powdered-NS is effective in order to improve the mechanical properties of cement mortar. They also mentioned that compressive strength and gel/space ratio of hardened mortar with powdered Nano-silica were better compared to colloidal Nano-silica. They further indicated that the powdered-NS acted as a filler to develop cement microstructure, which results in a denser morphology.

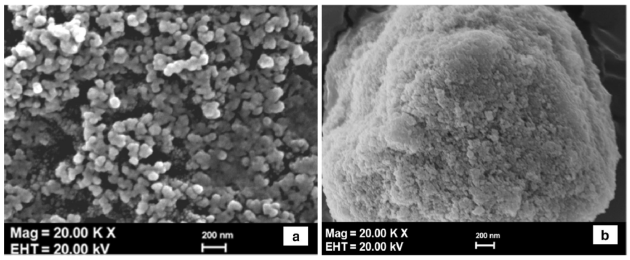

Figure 2 Powdered Nano-silica (a) and Colloidal Nano-silica (b) (Singh *et al*., 2015)

Biricik and Sarier (2014) asserted that the application of Nano-silica may be attributed to the improvement of the structural and mechanic properties of cement mortars and concrete in comparison with silica fume and fly ash.

Quercia *et al*. (2012) scrutinized the impact of adding two kinds of Nano-silica, i.e. fumed powder silica and precipitated silica in colloidal suspension, on mechanical properties and water permeability of concrete. They found that the compressive and tensile splitting strengths of the concretes increased by using the above-mentioned types of Nano-silica. They also reported that the maximum compressive strength was achieved by adding the colloidal Nano-silica while the maximum splitting tensile strength was obtained by addition of powdered Nano-silica.

Elboghdadi *et al*. (2015) detected substantial enhancement in the mechanical properties of concrete by adoption of Nano-silica; they attributed the improved mechanical properties to high pozzolanic activity, which leads to higher amount of C-S-H gel when nanoparticles are used to produce concrete.

In a study on the effects of colloidal Nano-silica on rheological and mechanical properties of fly ash-cement mortar, Hou *et al*. (2013) found that the addition of colloidal Nano-silica significantly increases the hardening process of fly ash-cement pastes. They reported that the paste with 40 percent fly ash replacement and 5 percent colloidal Nano-silica addition showed similar early and final setting times. They further mentioned that combination of fly ash and colloidal Nano-silicaenhances the viscosity of cement pastes. These authors also found that the early-age compressive strength of fly ash-cement mortars can be greatly improved by the addition of colloidal Nano-silica.

In addition, PrasadaRao and Maruthi (2016) revealed that production of concrete using a mixture of metakaolin and Nano-silicaenhanced strength in comparison with the usual concrete. They concluded that the concrete fortified by this mixturemay be used indifferent structural applications. They further explained that the improvement in the strength properties of the fortified concrete is attributed to the role of the added agents as binders in the fortified concretes. Additionally, TanveerHussain and Gopala Krishna Sastry (2014) found that using Nano-silica in cement can increase compressive strength, split tensile strength and flexural strength in concrete.

In a study to find the best percentage for incorporation of Nano-silica for production of concrete, Alam Shah *et al*. (2016) found that the highest level of elevation in compressive strength, flexural strength, split tensile strength and impact resistance are 47.90 percent, 52.91 percent, 33.33 percent, and 85.26 percent, respectively.

Effect of Nano-silica on durability of concrete

Singh *et al*. (2015) assessed durability of concretes with powdered and colloidal Nano-silica by monitoring chloride ingress in cement mortar. They found that powdered form of Nano-silicaresulted in reduction of the chloride ion concentration up to 43 percentin comparison with control cement mortar without Nano-silica.

TorabianIsfahani *et al*. (2016) found that durability properties of concrete with different water-binder ratios displayed exceedingly fluctuating tendency by growing Nano-silicaquantity. For a definite Nano-silicaquantity, they did not find any similarinfluence on concrete with diverse water-binder ratios. Additionally, they reported that the tendency of the variations as a function of water-binder ratio was not conserved by increasing Nano-silica content.

Durability can be increased by achieving higher levels of mechanical properties in concrete. Quercia *et al*. (2012) stated that addition of Nano-silica promotes the compressive strength and decreases the whole permeability of concrete because of the pozzolanic properties; this leads to a better hydration (C-S-H gel) and denser microstructure, which are known as Nano-filler and anti-leaching effects. This process may increase the durability of concrete structures, especially in marine environments. These authors examined the influence of adding two types of Nano-silica, i.e. fumed powder silica and precipitated silica in colloidal suspension, on durability of concrete. They evaluated durability by measuring conductivity, chloride migration, chloride diffusion, and freeze-thaw resistance and found that additions of 3.8% of both above-mentioned types of Nano-silica could improve durability with the latter with slightly better performance than the former.

CONCLUSION

Undoubtedly, concrete is the most widely-adopted building material in several civil engineering applications and therefore, any attempt to increase efficiency regarding the process of its production can lead to a high level of economic benefit. One of the most important challenges in using concretes is to improve its mechanical properties as well as its durability in different applications. Nano-silica has gained a lot of attention as an additive agent to the cement for production concrete due to its improving influence on mechanical properties and durability of the concretes. The present review summarized part of studies on the effect of Nano-silica on concrete; however, it seems that there should be more research to find out other effect of Nano-silica in concretes and proper dosage for various applications in different environments.

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How to cite this article:

DariushHajizadehAsl.2016, Application of Nano-Silica in Concrete to Improve Its Mechanical Properties and Durability: A Review. *Int J Recent Sci Res.* 7(6), pp. 12251-12254.

ISSN 0976-3031

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