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Review

Nano-SiO_2 contribution to mechanical, durability, fresh and microstructural characteristics of concrete: A review

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HIGHLIGHTS

- NS increases strength due to dense CSH gel mostly less than 5%.
- A small dosage of NS enhances the abrasion resistant.
- Using NS leads to the reduction of chloride ions penetration.
- Addition of NS to cement matrix improves the electrical resistivity.
- The incorporation of NS can increase the extent of shrinkage.

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ABSTRACT

Long-term durability of concrete has been of interest for researchers in past decades, and throughout their numerous research endeavors, they have tried to improve durability with the application of different methods. One technique is the integration of a new material into the concrete. One material that has attracted great attention of researchers is nano-SiO_2 (NS). Its considerable performance in the enhancement of durability properties of concrete and mortar provides reasonable specifications satisfaction for scholars. In this paper, important durability characteristics of concrete, including the chloride ion penetration, electrical resistivity, water penetration, water absorption, the pore size distribution, the carbonation, the sulfate resistance, frost resistance, shrinkage, and thermal properties were explored. Additionally, the effects on the microstructure of concrete and mortar in the previous studies were discussed. Mechanical properties, such as compressive strength, flexural strength, tensile strength, and abrasion resistivity were also investigated in the past and most recent papers.

Contents

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1. Introduction

Over the past few years, durability properties of cement-based products have attracted the attention of researchers more than their mechanical properties. In fact, an essential step for an enhancement in serviceability of different types of concrete structures is the improvement of their durability. There is a great inclination among designers for inclusion of new materials, which can be an excellent substitute for traditional materials in the production of a more durable concrete. Nano-material is one of the most effective materials, making a great contribution to the durability properties of mortar and concrete [1].

The main progress in concrete performance was attained by the application of super-fine particles. The optimal performance of these systems was attributed to the high-density continuous packings of the binder constituents, as shown in Fig. 1 [2]. Using these fine particles in mix-design will cause high fluidity levels. Nano-silica (NS) was found to be a very effective additive to concrete for improving strength, flexibility, and durability. NS can be used as an additive to improve workability and the strength of high-performance and self-compacting concrete as well [3]. Nano-binders composed of nano-sized cementitious materials, pozzolanic nanoparticles and a finely ground mineral additive-Portland cement mixture were proposed [4].

Based on a definition stated in 1981, a nano-material is considered to be a particle with dimensions between the interval of 1 and 100 nm. Nanoparticles play a major role in the improvement of mechanical and durability properties of concrete by providing great specific surface area, which leads to acceleration of pozzolanic reactions. Productions of pozzolanic reactions contribute to densification of the concrete structure at a microscale by decreasing porosity of concrete and amelioration of interfacial transition zone (ITZ) properties. It also fills pores with non-reactive particles in the presence of cement. All these improvements positively affect the mechanical and durability characteristics of concrete and mortar [5–8]. Nano-materials, such as nano-rice husk ash [8], nano-metakaolin [9], nano-TiO_2 [10], nano-Fe_2O_3, nano-Al_2O_3 were studied by different researchers because of their great performance in the improvement of concrete's properties. However, the most common and important nano-material in the production of concrete is NS.

In recent years, NS has turned into an effective material for the improvement of mechanical and durability properties of concrete. These improvements lead to a longer lifespan of concrete structures and a reduction in cost for repair of such structures as a result. One of the main problems regarding the production of Portland cement is the high amount of greenhouse gas emissions that will be produced in the process of cement clinker manufacturing. The addition of NS to cement-based materials, because of its unique properties, not only can notably reduce the amount of required cement in the production of concrete, but also can prevent consumption of raw materials in this process.

Many attempts have been done regarding nanosilica incorporation in the concrete industry. Each research experiment

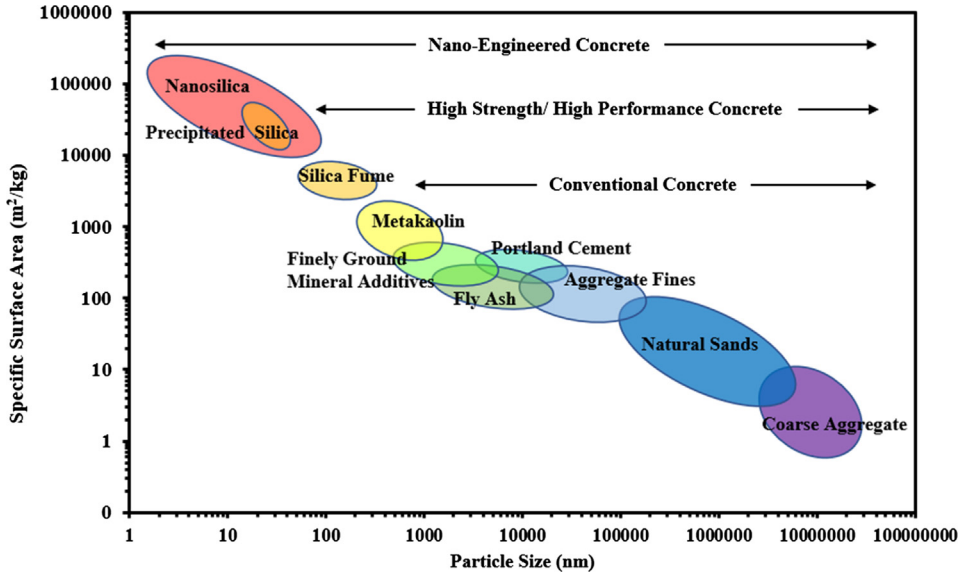

Fig. 1. The particle size and specific surface area scale related to concrete materials [2].