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Effect of using different types of nano materials on mechanical properties of high strength concrete

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HIGHLIGHTS

- We studied effect of NS and NF on Mechanical Properties of HSC.
- NS used in HSC can improve its mechanical properties more than NF.
- Increase of NS and NF more than optimum dose degrades the mechanical Properties.
- HSC containing granite gave better results than similar-containing dolomite.

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ABSTRACT

This study evaluates the effect of addition of nano silica, $Cu_{0.5}Zn_{0.5}Fe_2O_4$ (Cu-Zn ferrite) and $NiFe_2O_4$ (Ni ferrite) on the compressive strength, splitting tensile strength, flexural strength and modulus of elasticity of concrete. Nano-silica (NS), Cu-Zn ferrite and Ni ferrite, was added in five percentages (1%, 2%, 3%, 4% and 5%) of weight of cementitious materials (cement and SF). We use two types of coarse aggregate (dolomite and granite) and the study of the effect on the mechanical properties of concrete containing nano-materials. Results indicated that the optimum dose of nano-silica was 3% by weight and the optimum dose of Ni ferrite and Cu-Zn ferrite was 2% by weight. The samples of concrete-containing nano-silica gave better results from samples of concrete-containing nano ferrite and the approximate rate of about 10%. Also, the samples of concrete containing granite gave better results than similar-containing dolomite and the approximate rate of about 10%.

1. Introduction

During the period of the second half of the previous century, the terms "nano-science" and "nono-technology" were not yet familiarly used as today. However, they were really practiced and successfully applied to the progress in the field of material science and technology.

Nanotechnology is based on synthesizing nano-particles with specified characteristics to be used in different applications related to the industry, medicine, agriculture, etc. A nano-particle is a microscopic particle whose size is measured in nano-meters (nm). It is defined as a particle with at least one dimension less than 200-nm. During the last ten years, not only the nano-products were utilized to improve the quality and durability of products, but also new approaches were developed to handle traditional problems. Concrete is one of the most common and widely used construction materials. Its properties have been well studied at macro or structural level without fully understanding the properties of the cementitious materials at the micro level. The better understanding of the structure and behavior of concrete at micro/nano-scale could help to improve concrete properties [1].

Most of the published studies on the use of nano-particles in cement and concrete have utilized nano-oxides, especially SiO_2 and Fe_2O_3 [2–6]. Safan et al. studied the compressive strength of Portland cement pastes and mortars containing Cu-Zn nano-ferrite and found that the optimum dose of nano-ferrite was one percent of cement by weight and the increase in compressive strength of cement paste and mortar was increased by an average of 45% [7]. Zaki and Ragab studied the effect of NS on SCC. They used NS at

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different ratios of cementitious materials replacements (0.5%, 0.7% and 1%). They measured compressive strengths at ages 7, 28, 90 and 365 days. The results showed that 0.5% of NS replaced cementitious materials gave the higher compressive strengths through all ages [8]. Abbas carried out an investigation to study the influence of nano-silica addition on properties of conventional and ultra-high performance concretes and found that nano-silica (NS) concretes requires additional amount of water, since each kilogram of NS added required 0.4 kg of water to maintain the same workability. Also nano-silica addition resulted in significant early increase in compressive, splitting and flexural strengths of concrete in case of high cement content and low w/c ratio. Also, the addition of 5% nano-silica leads to an increase of 50% in 7-day compressive strength and 40% in 28-day compressive strength when compared with the same concrete without nano-silica [9]. Ji studied the water permeability of concrete containing nano-silica and found that the microstructure of concrete containing nano-silica is more uniform and compact, leading to reduction in water permeability [10].

2. Experimental work

In this work, the well known performance of concrete without nano particles was compared with that after the addition of nano particles for both fresh and hardened states. The used materials in the current research – except nano silica – were chosen from the available materials in Egypt.

2.1. Materials

2.1.1. Cement

Ordinary Portland Cement (OPC) produced by Sina Company was used in all mixes. The grade used was CEM I 52.5 N. Testing of cement was carried out according to the Egyptian Standard Specification (ES: 2421/2009). Table 1 shows the physical and mechanical properties of the used cement.

2.1.2. Aggregates

The aggregates used in this research work consisted of Crushed dolomite, siliceous sand, and Granite. To avoid the effect of fine materials in the coarse aggregate, it was washed 48 h before being used and left to dry.

2.1.2.1. Coarse aggregates. Local natural coarse aggregate from Ataka Mountain in Suez City was used in the experimental work. Two sizes of coarse aggregates were used. The coarse aggregates had nominal maximum size of 10 mm. Testing of coarse aggregate was carried out according to Egyptian Standard Specification (1109/2002). Table 2 shows physical properties of the used coarse aggregates.

2.1.2.2. Siliceous sand. The sand used in this investigation was natural siliceous sand. Testing of the used sand was carried out according to Egyptian Standard Specification (1109/2002). Table 3 shows the sand physical properties.

2.1.3. Silica fume

The used silica fume was brought from Sika Company in Egypt. The physical and chemical composition is shown in Tables 4 and 5, respectively, as obtained from the manufactures sheet.

2.1.4. Superplasticizer

A high range water reducer (HRWR) of modified polycarboxylates was used in the experimental work of the study. This admixture is conforms to ASTM C494 (types F and G).

It is derived directly from the total Performance Control concept. Its particular configuration allows its delayed absorption onto the cement particles and disperses them efficiently. As compared with other PCE superplasticizers, it is possible to

Table 2
Physical properties of the coarse aggregates used.

Property	Crushed dolomite	Granite	Limits*
Specific weight	2.68	2.71	–
Bulk density (t/m^3)	1.62	1.65	–
Void ratio (%)	39.5	39.11	–
Water absorption (%)	2.00	0.3	Not more than 2.5%
Crushing value (%)	22.5	18.2	Not more than 25%
Coefficient of abrasion (%)	18.3	18	Not more than 30%
Coefficient of impact (%)	9.5	13.1	Not more than 30%

* The limits are according to Egyptian Standard Specifications No. (1109/2002).

Table 3
Physical properties of the sand used.

Test	Siliceous sand
Specific weight	2.66
Bulk density (t/m^3)	1.86
Fineness modulus	2.65
Void ratio (%)	36.84

Table 4
Physical properties of the silica fume used.

Property	Results*
Specific surface area (m^2/kg)	17.8×10^3
Particle size (μm)	7.00
Bulk density (kg/m^3)	345
Specific gravity	2.15
Color	Light gray

* By the manufacturer data sheet.

Table 5
Chemical composition of the silica fume used.

Oxide	Content (%)*
SiO_2	96.00
Fe_2O_3	1.45
Al_2O_3	1.10
CaO	1.20
MgO	0.18
K_2O	1.20
Na_2O	0.45
SO_3	0.25
H_2O	0.85

* By the manufacturer data sheet.

Table 1
Physical and mechanical properties of the Portland cement used CEM I 52.5 N.

Properties		Test result	Limits*
Percentage of water for standard consistency (%)		29.5	–
Specific surface area (Blain) (m^2/kg)		350	Not less than 275
Specific weight		3.15	–
Soundness (Le-Chatelier) (mm)		1.0	Not more than 10
Initial setting-time (min)		80	Not less than 45 min
Final setting time (min)		190	–
Compressive strength of standard mortar	2 days (MPa)	22.3	Not less than 20
	28 days (MPa)	54	Not less than 52.50

* The limits are according to Egyptian Standard Specifications (4756-1/2009).