Experimental analysis of SiO2 and CNT nanoparticles effects on the compressive strength of the concrete

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Abstract

This article is focused on the compressive strength of the concrete using silica oxide (SiO2) and carbon nanotube (CNT) nanoparticles. The concrete samples are mixed with a combination of nanoparticles with different percentages. Since the nanoparticles are not solved in water without any specific process, before producing concrete samples, nanoparticles are dispersed using a shaker, magnetic stirrer, ultrasonic devices, and finally mechanical mixer. The 15*15*15 cm cubic concrete samples for determining the compressive strength are built in three cases high SiO2, and low CNT volume percent, low SiO2 and high CNT volume percent, and pure CNT without SiO2. The 28 days cubic concrete samples are tested by ELE ADR 2000 machine. The results show that in a constant SiO2 volume percent, the compressive strength is improved by increasing the CNT volume percent, while in a constant CNT volume percent, enhancing the SiO2 volume percent has no good effect on the compressive strength. In addition, the combination of two nanoparticles cannot increase the compressive strength with respect to the sample without nanoparticles. Hence, the best result is related to the concrete containing pure CNT nanoparticles with 0.4%, which increases the compressive strength of the concrete by about 75%.

1. INTRODUCTION

Due to the different static and dynamic loads in concrete structures, the improvement of the compressive strength is very important. One of the best ways for improving the compressive strength is using nanoparticles. In this paper, the effect of two nanoparticles of silica oxide (SiO2) and carbon nanotube (CNT) is studied.

In the field of nanoparticles effect on concrete structures, Joseph et al. [1] presented the results of a series of self-healing experiments conducted on reinforced mortar beams containing adhesive-filled glass reservoirs. Dry [2] studied the repair or healing of cracks and filling of voids in cementitious matrices by the internal release of repair chemicals from inside fibers into the hardened matrix. As synthetic polymers, currently used for concrete repair, may be harmful to the environment, the use of a biological repair technique was investigated by Tittelboom et al. [3]. Tittelboom and De Belie [4] presented the types of healing agents and capsules applied. Nano-materials for corrosion control in reinforced concrete were studied by Koleva et al. [5]. Qian et al. [6] investigated the self-healing behavior of Engineered Cementitious Composites (ECC) with a focus on the influence of curing conditions and precracking time. Kanellopoulos et al. [7] presented the encapsulation mineral compounds as healing materials for cement-based composites. Three liquids (sodium silicate, colloidal silica, and tetraethyl orthosilicate) and one powdered (magnesium oxide) mineral were encapsulated in thin-walled soda glass capsules. Li et al. [9] presented in situ polymerization with a melamine urea-formaldehyde resin shell and an epoxy resin adhesive. Mohajeri and Goher [10] investigated the nanocapsule with a polymer core and silica coating as cement additive for concrete with self-healing property. New self-healing material for concrete repair was fabricated by Tan et al. [11] through microencapsulation of silica sol via interfacial polymerization of poly (urea-urethane). Self-healing microcapsules were synthesized by Ahn et al. [12] and examined the applicability and limitation of various ultrasonic test methods in assessing self-healing performance. Microcapsules, with sodium silicate solution as core, were produced by Kanellopoulos et al. [13] using complex concertation in double, oil-in-water-in oil, emulsion system. Dong et al. [14] presented the development of self-healing materials that hold promise for the permeability healing of concrete or other cementitious composites. UHPC was developed by Calvo et al. [15] incorporating an innovative self-healing system based on two micro/nano-additions: silica microcapsules containing epoxy sealing compound (CAP) and amine-functionalized silica nanoparticles.

The effects on transmission of chloride were tested by Ling and Qian [16] through multiple methods. Vijay et al. [17] reviewed the types of bacteria employed in concrete and the ways they can be applied as healing agents. The feasibility of expanded perlite (EP) as a novel bacteria carrier in quantifying cracks-healing in concrete via immobilization of Bacillus cohnii was demonstrated by Zhang et al. [18]. Self-healing concrete by bacterial and chemical admixtures was investigated by Shaikh and John [19]. Palin et al. [20] presented a bacteria-based self-healing cementitious composite for application in low-temperature marine environments. Evaluation of self-healing concrete attributes as a sustainable and smart construction material was studied by Fahim Huseien et al. [21]. Niewiadomski and Hoła [22] studied the failure process of compressed self-compacting concrete modified with nanoparticles assessed by the acoustic emission method. Abhilash et al. [23] investigated the effect of nano-silica in concrete. Microstructural study and surface properties of concrete pavements containing nanoparticles were presented by Ghoddousi et al. [24]. Meddah et al. [25] studied mechanical and microstructural characterization of rice husk ash and Al2O3 nanoparticles modified cement concrete. Kumar et al. [26] presented the influence of various nano-size materials on the fresh and hardened state of fast-setting high early strength concrete.

To the best of the author's knowledge, no report has been found in the literature for the study of SiO2 and the CNT nanoparticles effect on the compressive strength of concrete. Hence, this research, approach, and results are completely new and nobody published it elsewhere. The objective of this work is to investigate compressive strength with various volume percent of nanoparticles and introduce the best condition.

2. SAMPLES' PREPARATION

In order to build the samples, a national mixed design as shown in Table 1 is used.

Table 1. The proposed mixed design for the construction of concrete samples

W/C	Slump	Quantities (kg/m3)				
		Water	Cement	Coarse Gravel	Fine Gravel	Sand
0.4	5-8 cm	240	600	355	530	650

Since the nanoparticles are not solved in water without any specific process, before producing concrete samples, nanoparticles are dispersed by using a shaker, magnetic stirrer, ultrasonic devices, and finally mechanical mixer based on the number of used nanoparticles than cement at specific times. This procedure is shown in Fig.

Figure 1. The procedure of dispersing nano-capsules in water (a) shaker (b) magnetic stirrer (c) ultrasonic devices (d) mechanical mixer.

In order to determine the average compressive strength of the concrete, cubic samples with 150x150x150 mm dimensions are used and the compressive strength development process is studied for 7, 14, and 28-day ages. This test is done using an automatic concrete pressure test machine ELE ADR 2000 as shown in Fig. 2a with the broken sample presented in Fig. 2b.

(a)

(b)

Figure 2. (a) Automatic compression machine for determining the compressive strength of the concrete (b) broken sample

3. EXPERIMENTAL TESTS AND RESULTS

The compressive strengths of the cubic samples are given in Table 2 and Fig. 3 for high SiO2 and low CNT volume percent. Based on the obtained results:

- Increasing the CNT volume percent, increase the compressive strength, but is lower than the sample without nanoparticles .
- The worst results are related to high SiO2 and low CNT volume percent.
- In 0.15 CNT volume percent, with increasing the SiO2 volume percent, the compressive strengths are improved while in 0.2% and 0.25% CNT volume percent, this is the converse.

Table 2. The compressive strength of samples for high SiO2 and low CNT volume percent

Number	Volume percent	Force (KN)	Compressive strength (MPa)
1	Without nanoparticles	838.2	37.25
2	0.15%CNT+3% SiO2	351.1	15.61
3	0.15%CNT+2% SiO2	317.7	14.12
4	0.20%CNT+1.5% SiO2	572.3	18.98
5	0.20%CNT+1.0% SiO2	618.4	27.48
6	0.25%CNT+0.5% SiO2	568	25.24
7	0.25%CNT+0.25 %SiO2	690.8	30.7

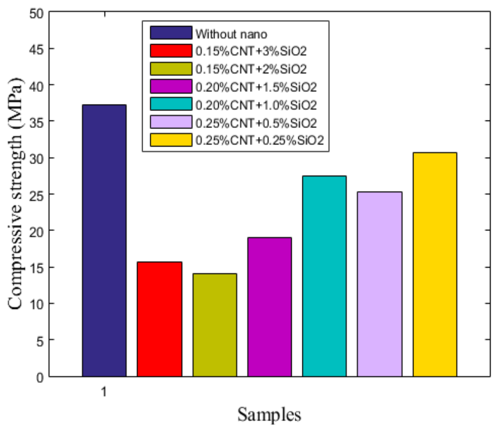

Figure 3. The compressive strength of samples for high SiO2 and low CNT volume percent

The compressive strengths of the cubic samples are given in Table 3 and Fig. 4 for low

SiO2 and high CNT volume percent. Based on the obtained results:

- In a constant CNT volume percent, the SiO2 nanoparticles have no good effect on the compressive strength.
- Pure CNT without SiO2 nanoparticles has better compressive strength and hence it can be concluded that the combination of SiO2 and CNT nanoparticles is not good.

Table 3. The compressive strength of samples for low SiO2 and low CNT volume percent

Number	Volume percent	Force (KN)	Compressive strength (MPa)
1	Without nanoparticles	989.8	43.98
2	0.25%CNT+0.1% SiO2	732.1	32.53
3	0.25%CNT+0.2% SiO2	650.2	28.90
4	0.30%CNT+0.1% SiO2	666.6	29.63
5	0.30%CNT+0.2% SiO2	655.2	29.12
6	0.35%CNT+0.1% SiO2	631.5	28.07
7	0.35%CNT+0.2% SiO2	598	26.57

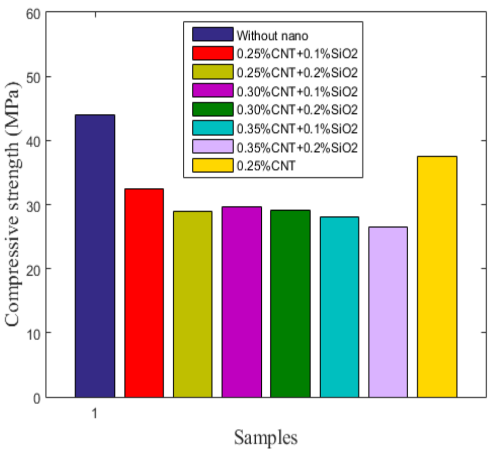

Figure 4. The compressive strength of samples for low SiO2 and high CNT volume percent

The compressive strengths of the cubic samples are given in Table 4 and Fig. 5 for pure CNT volume percent. Based on the obtained results it is found that the best volume percent is 0.4% CNT, which in this case, the compressive strength is enhanced by about 75%.

Table 4. The compressive strength of samples for pure CNT volume percent

Number	Volume percent	Force (KN)
1	Without nanoparticles	39.17
2	0.2%CNT	38.54
3	0.4%CNT	68.59
4	0.60%CNT	34.59

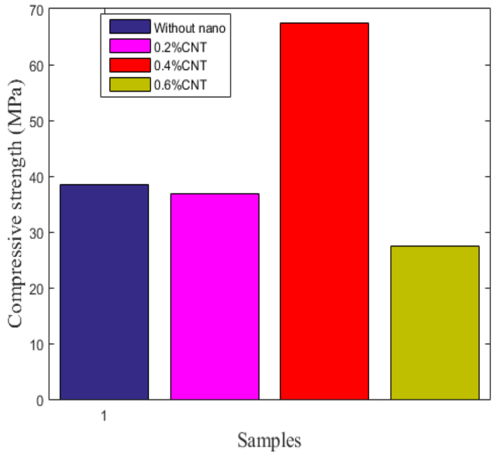

Figure 5. The compressive strength of samples for pure CNT volume percent

4. CONCLUSION

The compressive strength of the concrete using SiO2 and CNT nanoparticles was presented in this study. The concrete samples were mixed with a combination of nanoparticles with various percentages. Since the nanoparticles are not solved in water without any specific process, before producing concrete samples, nanoparticles were dispersed using a shaker, magnetic stirrer, ultrasonic devices, and finally mechanical mixer. The 15*15*15 cm cubic concrete samples for determining the compressive strength were built in three cases high SiO2 and low CNT volume percent, low SiO2 and high CNT volume percent, and pure CNT without SiO2. The 28 days cubic concrete samples were tested by ELE ADR 2000 machine. The results show that:

- Increasing the CNT volume percent, increase the compressive strength but was lower than the sample without.
- The worst results were related to high SiO2 and low CNT volume percent.
- In 0.15 CNT volume percent, with increasing the SiO2 volume percent, the

compressive strengths were improved while in 0.2% and 0.25% CNT volume percent, this is the converse .

- Pure CNT without SiO2 nanoparticles has better compressive strength and hence it can be concluded that the combination of SiO2 and CNT nanoparticles was not good .
- It was found that the best volume percent is 0.4% CNT, which in this case, the compressive strength is enhanced by about 75%.

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