Journal of Structural Engineering and Geotechnics,
11(1),45-56,Winter and Spring 2021

Mechanical Properties of Low Strength Concrete Incorporating Carbon Nanotubes

Meysam Morsali [a], Reza Farokhzad [a,*]

[a] *Department of Civil Engineering, Qazvin Branch, Islamic Azad University, Qazvin, Iran*

Received 18 October 2020, Accepted 17 November 2020

Abstract

Nowadays, due to the increasing population and the expansion of urbanization, and consequently the need for high-rise and multi-storey buildings that , the safety and resistance of the load bearing members of the structures has become of interest to researchers. For this purpose, different approaches have been proposed, including nanomaterials as a suitable and optimal method. Using nanomaterials as a percentage of cement weight improves concrete performance and increases its strength. Since these materials should be used at the beginning of concrete construction, therefore, they cannot be used in constructed structures. But a protective coating containing these nanomaterials can enhance and improve the performance of the structures, which is applicable to the fabricated structures. The purpose of this study was to investigate the effect of protective coatings with Nano silica, carbon nanotube and graphene nanomaterials. For this purpose, four thicknesses different and 2% nanomaterials different, the effect of thickness and percentage of nanomaterials were investigated. The results show that the sample containing 15% of silica with 26.74 N/mm^2 has the highest effect compared to other nanomaterials. However, due to the low percentages of carbon nanotube and graphene, these materials have a significant effect.

Keywords: carbon nanotubes, Micro silica, graphene, the compressive strength of concrete, protective cover

1-Introduction

Due to the extensive use of concrete and very important role in the development of the country's infrastructure And the need for innovation in construction technology in Iran to provide earthquake resistance, extend the life and durability of structures, reduce construction costs and.... Studies of concrete and cement paste at the nanoscale and the application of these materials are very important. Also Significant progress in the industry, Concrete technology and Increasing innovations Including nanotechnology requires that In the field of materials and construction methods, Possibility of production and access to nano-concrete for application To be explored as soon as possible. The use of nanoparticles in materials development has been introduced in many fields. It seems that in the near future significant developments in concrete technology will be created. (1) Observations have shown that the presence of nanoparticles in concrete and mortar construction strongly affects its physical and chemical properties. And its immersion in building materials leads to the formation of new products with some prominent properties. The properties of cementitious materials are based on their pozzolanic activity. Therefore, adding nanoparticles can improve the pozzolanic activity of cement, which increases the strength of cement paste. In addition, apped nanoparticles can reduce porosity by filling the cement pores, which improves the properties of mortar or fresh concrete. (1)

According to studies, researchers have found that the use of nanomaterials reduces porosity in the concrete and greatly increases its strength [2-5]. One of the

*Corresponding Author: Reza Farokhzad ail:R.farokhzad@qiau.ac.ir

main reasons for the low strength of concrete compared to steel. Porosity is in the microstructure of concrete. Many efforts have been made to address this issue, especially in the field of nanotechnology [6]. Morteza Beigi et al (4) their research has shown that adding nano-silica to concrete reduces water absorption they also observed that the water absorption rate of 4% nano silica in the concrete mixture was lower than the other percentages of nano silica addition. Jo et al. [3] showed in their research that the compressive strength of all mortars with nanosilica particles was higher than that containing silica fume at 7 and 27 days and It was also shown that the compressive strength of mortars increases with increasing nanosilica percentage from 3% to 12%. Abolfazl Asghar Nikan et al (7) In their research studied the effect of carbon nanotubes on cement with blowy gray. And observed that carbon nanotubes added to micro –structure of cement that became denser containing blowy gray and its compressive strength increased compared to that without the nanotube. Ibrahim Khalil Zadeh Vahidi [8] in his research the effect of Nano silica on permeability and microstructure of concrete was investigated. And observed a decrease in permeability and improvement of its microstructure. By adding nano-silica, it reduces the weak calcium hydroxide crystals and gel production (CSH), which this gel thickens the concrete microstructure and increases its strength. these nanoparticles are used for making cement compositing 2 forms(9) :1-in concrete mix structure 2-in protective cover (that enclose round of concrete like a cover that causes increasing pushing resistance of concrete).since most studies are aimed at investigating the effect of Nano composites as an additive in concrete and on the other hand , The first method (using nano-materials in concrete) cannot longer be used, so in this study we investigate the effect of nano-materials in the form of concrete cover.

2- Nanoparticles and their Effect on Concrete Microstructure

Nanotechnology is not a new discipline, but a new approach in all disciplines. Nanomaterials are defined as materials having at least one dimension (length, width, or thickness) below 100 nm. A nanometer is about one thousandth of a micron or 100,000 times smaller than a human hair. Nanotechnology has had wide applications in various fields including food, pharmaceutical, medical, biotechnology, electronics, computers, environmental, aerospace and more. In the field of road and construction, this technology also makes a private contribution and In recent years, much research has been done to add nanoparticles to cement [10-11]. A combination of cement powder and aggregate (different size) and water (physical , mechanical and chemical properties) make concrete a very heterogeneous material .The reaction between cement and water produces calcium silicate hydrate and It causes resistance and other mechanical properties of concrete as well as some byproducts such as calcium hydroxide (CH), gel pores, etc. The presence of calcium hydroxide has no effect on increasing the strength of concrete and on the other hand, the presence of gel cavities decreases the strength of concrete. By-products during cement hydration are expressed in terms of (1) [12]:

$$C_3S + 6H \rightarrow C_3S_2H_3 + CH_2$$
$$C_2S + 4H \rightarrow C_3S_2H_3 + CH_2 \qquad (1)$$

In the above relation C represents the chemical symbol of cement; S represents silicon oxide (SiO2) and H represents water (H_2O). According to the above equation, calcium silicate hydrate (CSH) is the cement strength phase, while the byproduct (CH) lacks any cementitious properties and breaks easily due to sulfate attack. Adding appropriate silica or aluminum cement to the mixture can increase the cement's resistance because they react with calcium hydroxide (CH) and produce calcium silicate hydrate (CSH), which then causes calcium hydroxide (CSH) to form.

Improve concrete microstructure, reduce porosity and increase concrete strength. Figure 1 shows the dense structure of calcium silicate hydrate (CSH) [12-13].

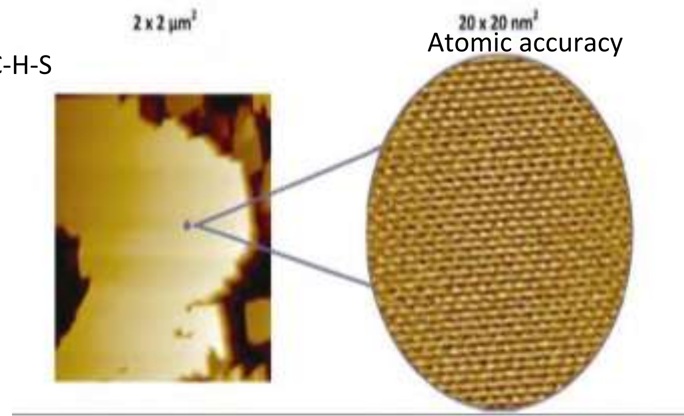

Fig.1: Crystalline C-H-S nanostructure in calcite layer by AFM[13]

Following the introduction of nanomaterials used in this research is discussed.

2.1. Nanosilica

In terms of physical properties, the specific surface area of nano-silica is usually 60-600 m 2 / g. Also the specific density is between 30-40 g / l. Nano-silica is highly active due to its high surface area and can react rapidly with calcium hydroxide crystals to produce hydrated calcium silicate gel. Therefore, the size and amount of these crystals in concrete decreases. On the other hand, the hydrated calcium produced fills the cavities in the concrete and improves the bonding between aggregates and cement paste [14]. About 60% of the product due to hydration of water and cement is hydrated calcium silicate gel. The average diameter of hydrated calcium silicate is about 10 nm, so nano-silica can fill holes in the structure of hydrated calcium silicate gel and cause better locking and closure of this phase [15].

Carbon Nanotubes (CNT)

The nanotubes were discovered by Samio Ijima[16] in 1991. Carbon nanotubes can be thought of as single-walled graphite sheets or sheets such as tubular sheets or multi-walled sheets similar to multiple sheets (Fig. 2) [9 and 18-17].

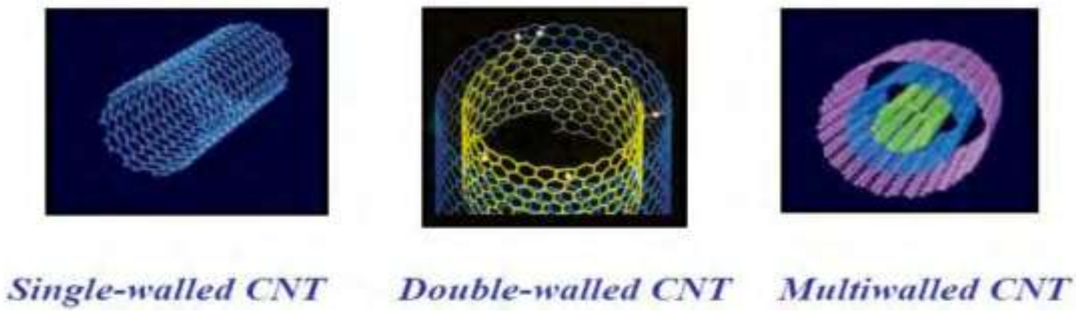

Fig. 2: Types of carbon nanotubes [19]

Carbon nanotubes are tubular shaped graphite plates with a diameter of about nm and have high mechanical properties [20]. Carbon nanotubes (CNTs), now known as the 21st century material, are of great importance because of their remarkable mechanical properties. The range of applications of carbon nanotubes varies widely in the electronics, biological and chemical sectors to multi-functional composites. According to research reports, carbon nanotubes have a very high theoretical resistance to boiling, although 100 times higher than steel, but 6 times lighter in weight, as a result of carbon atoms forming a favorable structure. [21-25]. The Yang coefficient and tensile strength of this structure are more than 1 GPa and GPa 200, respectively [25]. Because of its high mechanical properties, carbon nanotubes are used in multiple composites to enhance the respective matrix [25].

2-2. Graphene

Due to the hydrophobic properties of graphene does not disperse well into water and it become in to form clusters stuch together. Therefore, with oxidizing graphene and induction of oxygenated functional groups increases it. And then converted to graphene using graphene oxide heat recovery inside the concrete and the hydrophobic property and its electrical conductivity are restored. There have been few studies in the world on the use of graphene in concrete. Since graphene and its effects are not well known, so most papers have investigated the initial impact of using this material on hydrated cement paste. Figure 3 shows the morphology of hydrated Portland cement graphene composite and nanocomposite structure using SEM imaging [25].

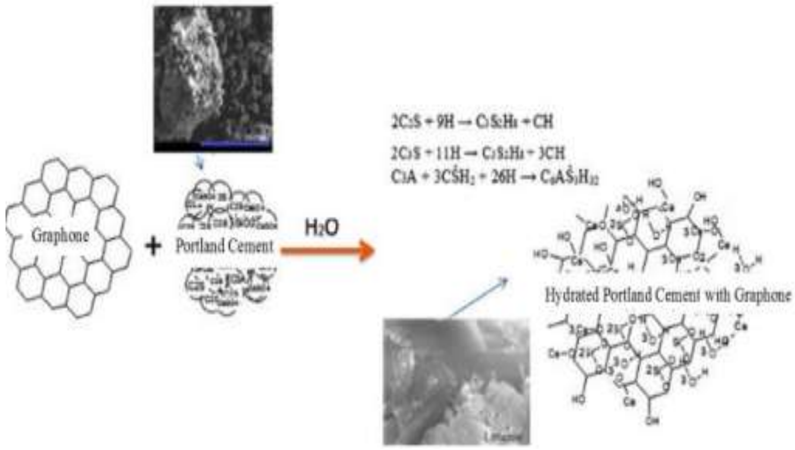

Fig.3: Schematic image of hydrated cement graphene composite and nanocomposite structure [25]

3- Laboratory Activities

In this study, the effect of using silica nanoparticles, graphene and carbon nanotubes on the compressive strength of low strength concrete is investigated. To evaluate the compressive strength, the specimens are pressurized by a hydraulic jack at a loading speed of 300 kg / s.

The control concrete specimen has a 28-day dry density between 1120 and 1920 kg / m3 and a 28-day compressive strength of 16 to 18 MPa. On the other hand, in order to investigate the effect of nanomaterials on compressive strength of concrete, core concrete is investigated by mortar coatings containing nanosilica, carbon nanotube and graphene with different percentages and thicknesses. The mix design is made up of the names A, B, C, D, E, F, G, H, I and J. The A-design is for core concrete that has a strength of between 16 and 18 MPa without additives. Designs B, C and D are related to non-additive mortars, respectively, to obtain suitable mortars for the manufacture of nanomaterial coatings around the core concrete. Samples E to J correspond to the carbon nanotube HAWA ratios in the ratios of 0.05 and 0.1%, silica to the ratios of 10 and 15%, respectively, and graphene to the ratios of 0.05 and 0.1 wt.%, respectively (Table 1). For each mixing scheme according to different thicknesses (2, 3, 4 and 5 cm) of coating containing carbon nanotube, microsilica, graphene as well as control concrete, about 28 specimens were used to determine the compressive strength according to ASTM C39 standard. The 28-day-old is molded.

Table 1
Mix Design of All Samples

Lubricant (polycarboxylate) (Kg)	Additive value (Kg)	Type and percentage of (Kg) additive	Water (Kg)	Big aggregate (Kg)	small aggregate (Kg)	Cement (Kg)	Sample
-	-	-	155	700	400	300	A
15	-	-	270	-	1050	800	B
15	-	-	255	-	1050	800	C
15	-	-	240	-	1050	800	D
15	30	0/05 Graphene	255	-	1050	600	E
15	60	0/1 Graphene	255	-	1050	600	F
15	30	0/05 Nanotube	255	-	1050	600	G
15	60	0/1 Nanotube	255	-	1050	600	H
15	60	%10 Micro silica	255	-	1050	600	I
15	90	%15 Micro silica	255	-	1050	600	G

The materials used in the construction of the concrete used in this study are: Portland cement type II Abyek cement plant, carbon nanotube, nanosilica, graphene, sand and drinking water of Hadid Industrial Estate. The specifications for the cement, sand and sand grading curves are shown in Table 2, Table 3 and Figure 4, respectively.

Table 2
Portland Cement Specifications Type II Abyek Cement Factory

Consumed cement oxides	Percentage of cement oxides	Percentage of Oxides of 389 Standard Cement in Iran	Comparison of Cement Used 389 Standard Iran
CaO	59/64	63-66	Allowed
SIO_2	20/76	20-22	Allowed
AL_2O_3	5/4	5/5-7/5	Allowed
Fe_2O_3	3/8	3-6	Allowed
SO_3	1/73	1-3	Allowed
C3A	7/88	8-6	Allowed
MgO	2/18	5-2	Allowed
313 :(m2/kg) special surface		3150 :(Kg/m3) Special Weight	

Table 3
Physical Properties of Natural Aggregates

aggregates	Water absorption percentage	Density (T / m3)	Modulates sand softness	Maximum diameter of aggregates
Natural sand	1/7	2/6	3/61	2

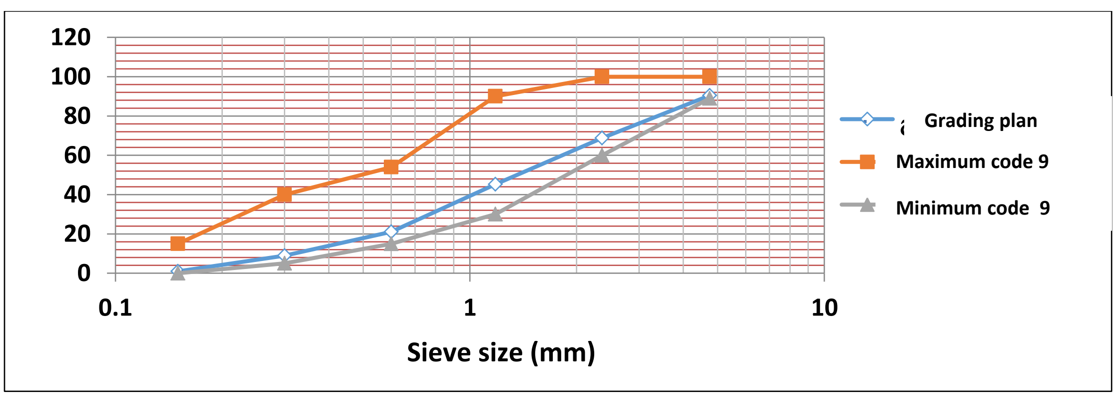

Fig 4: sand gravel curve

For concrete mixing in the laboratory, a rotary – moving concrete mixer is used. in this machine the mixing is done homogeneously .after weighing the amount of material needed for each mixing scheme the sand is first poured in to the machine, then cement mixed with water is added and the machine is turned on for 150 secends.to make the mixing process work well.in this mixing 50%of the mix design water is added to the mixture and the mixture continues. After3 min add the rest of the water and continue mixing for 3 min. after mixing and preparing the concrete, the concrete is discharged immediately by slip test on the mixture and if it is accepted the concrete is poured in to cylindrical molds (in 5 layers) and compressed using a vibrating machine. Lt should be noted, however, hat all of the above steps for coating are made, with the addition of carbon nanotubes, silica and grapheme for coating. After obtaining a mixing design for the 300 grade Core Concrete, these concrete are sampled in 15 cm molds and then removed for 24 hours and molded into larger molds of 17 cm size. , 18, 19 and 20 cm (Figs. 5 and 6). Then, mortars with strength of between 40 and 50 MPa are prepared with nanomaterials and cast in the vacuum between the core core mold and the mold. Finally, after 24 hours, the samples were removed from the mold and placed in a water basin for 28-day resistance.

Fig.5: Central core with protective cover

4- Results And Discussion

Since the aim is to evaluate the impact of coatings containing nanomaterials on core concrete, so to obtain core concrete with mixing scheme A (low strength concrete) as well as mortar with resistance between 40 and 50 MPa (specimens with design) . Mixing B to D) were subjected to a compression test. The results of compressive test of core concrete and coating mortar are shown in Figures 6 and 7, respectively

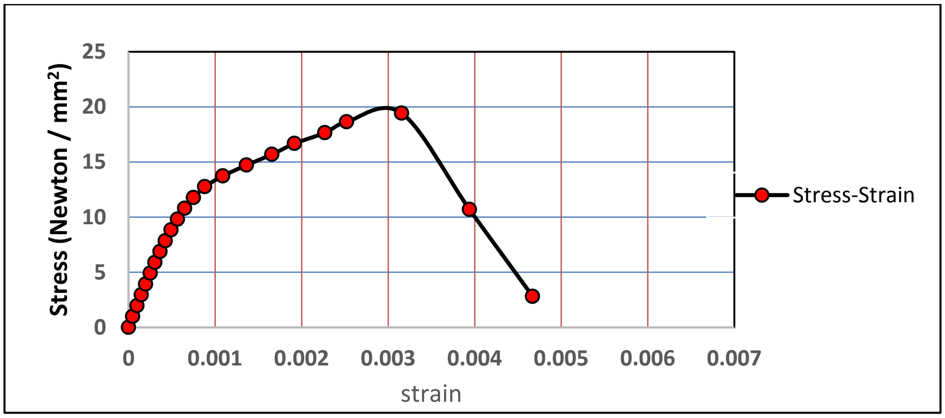

Fig.6: Stress-strain graph of core concrete

To investigate the effect of nanomaterials on core concrete strength, microsilica, graphene and carbon nanotubes with different percentages as coating additives were used. The results of the compressive test for samples containing nanomaterials are shown in Figures 7 to 9.

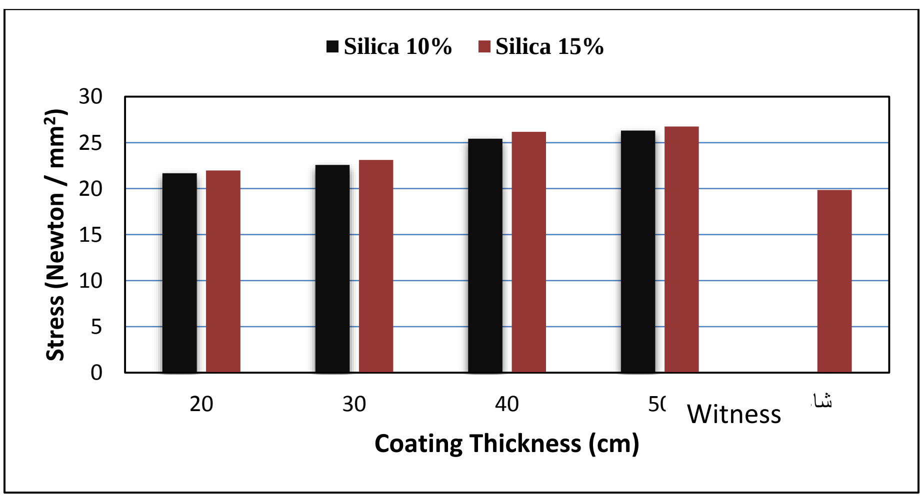

Fig.7: Comparison of compressive strength of specimens with coating with 10% and 15% microsilica

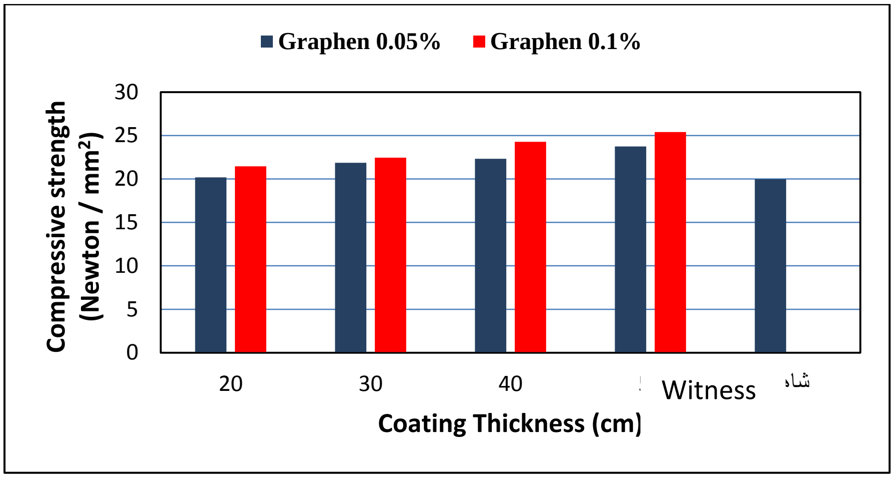

Fig.8: Comparison of compressive strength of specimens with coating with 0.05% and 0.1% grapheme

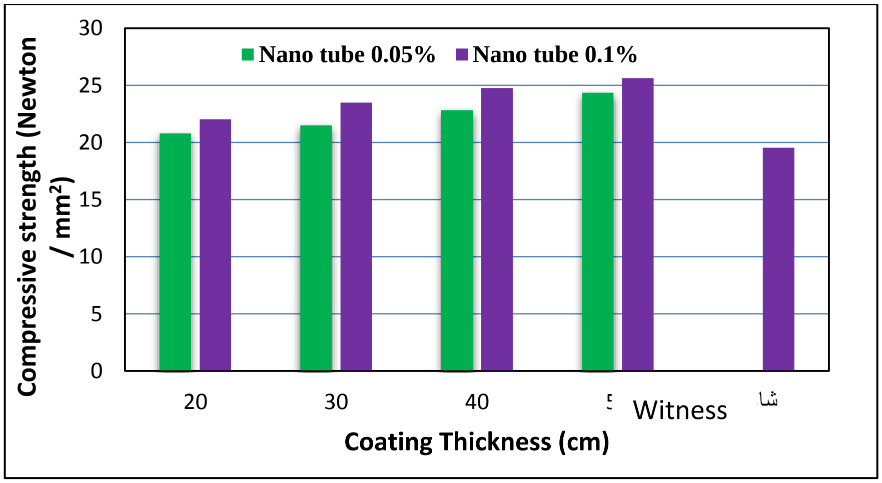

Fig.9: Comparison of compressive strength of samples containing 0.05 and 0.1% carbon nanotube

The results show that with increasing nanoparticles percentage and coating thickness in all three cases, there is always an increase in strength. The highest and lowest resistance in samples containing silica, graphene and nanotube were 26.74 and 21.97, 25.41 and 21.46 and 25.63 and 22.03 MPa, respectively. Figure 10 shows the results of all samples containing nanomaterials.

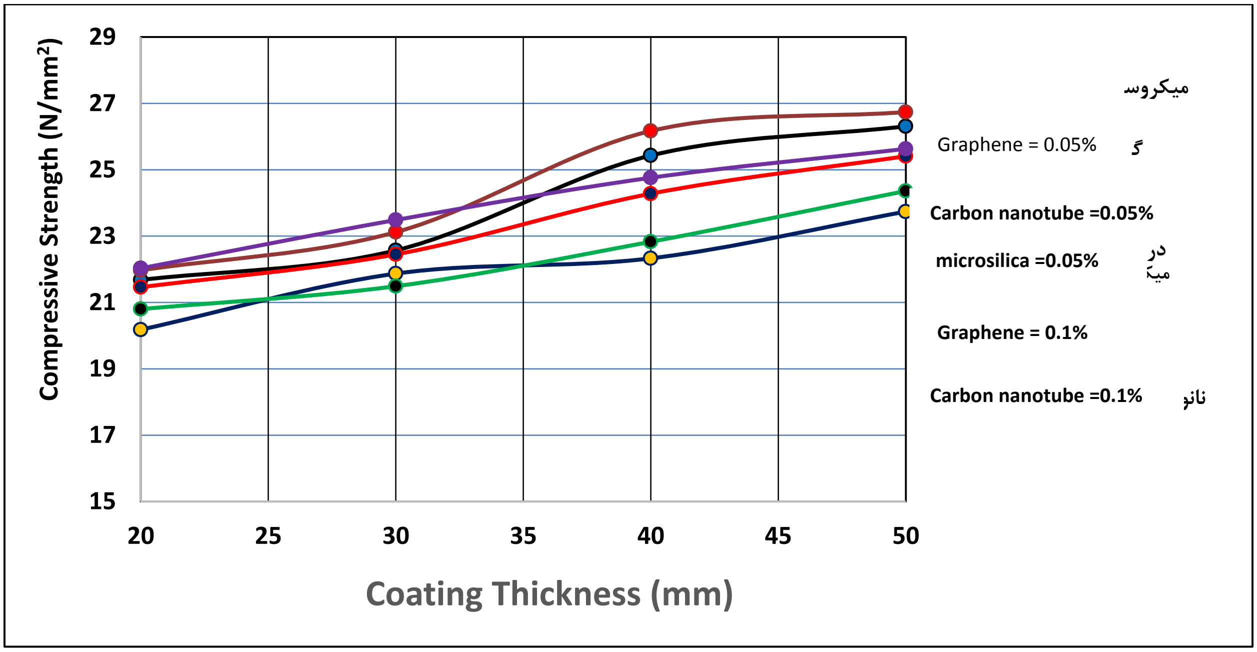

Fig.10: Comparison of the effect of different types of nanomaterials on compressive strength of the samples

By comparing the results for all three nanomaterials, it can be seen that the compressive strength of the sample containing microsilica at two percentages of 15 and 10 is higher than the rest. After microsilica, the sample containing 0.1% carbon nanotube and graphene are next in order. Finally, two 0.05% nanotube and graphene samples are in the last step in terms of compressive strength. Therefore, it can be concluded that silica has more positive effect than carbon nanotube and graphene.

5- Conclusion

In this study, the effects of using different percentages of microsilica, graphene and carbon nanotubes as an additive in the form of a coating as well as the effect of thickness of this coating to increase the compressive strength of core concrete were investigated and the following results were obtained:

- Increasing the percentage of nanosilica, graphene and carbon nanotubes has always led to increased compressive strength of core concrete.
- Increasing the thickness of the coatings containing nanomaterials increases the compressive strength of the core concrete.
- Based on the results, it was found that silica has a greater effect on compressive strength of core concrete than graphene and carbon nanotube.

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