Advances in Nanomedicine and Nanotechnology Research
ANNR, 2(1): 89-92
www.scitcentral.com
ISSN: 2688-5476
Original Research Article: Open Access

The Effects of Graphene and Graphene Oxide Platelets on Morphology and Mechanical Properties of Cement Mortars

Farani MR[1*], Ahmadzadeh M[1], Vahdat A[2], Barkati M[3] and Ebrahimi SH[4]

*[*1]School of Chemical Engineering, University College of Engineering, University of Tehran, Tehran, Iran*
[2]Department of Civil Engineering, Sharif University of Technology, Tehran, Iran
[3]Department of Material and Metallurgy, University of Semnan, Semnan, Iran
[4]School of Science and Engineering, Sharif University of Technology, International Campus, Kish Island, Iran.

Received August 09, 2019; Accepted September 05, 2019; Published June 26, 2020

ABSTRACT

In the present study, nanoparticles of graphene and graphene oxide without functionalizing the surface were added to the concrete blend and the effects of these particles on morphology and mechanical properties were investigated. Three samples containing 0.28, 0.56 and 1.1 weight percent graphene and 3 samples with these weight percents containing graphene oxide were prepared and the properties of these samples were investigated with those of pure cement mortars. The results show that the compressive strength of the samples containing both graphene and graphene oxide increase significantly.

Keywords: Nanoparticles, Nanocomposites, Graphene nanoplatelets, Electrical properties

INTRODUCTION

In recent years, nanotechnology applications have been growing in different domains. Because of their unique properties, nanoparticles have been gaining increasing attention and been applied in many fields to fabricate new materials with novelty functions. Many scientific articles have been published and within the next few years large investments will be accomplished in this area [1,2]. In Civil Engineering, major development has been achieved through the production of materials with new functions or by improving the performance of existing ones [3]. If nanoparticles are integrated with traditional building materials, the new materials might possess outstanding or smart properties for the construction of super high-rise, long-span or intelligent civil infrastructure systems [4].

Graphene nanoplatelets, a two-dimensional monolayer of sp2-bonded carbon atoms, have unique mechanical, thermal and electrical properties, large specific surface area and low manufacturing cost that make them ideal reinforcing materials. However, very little work has been reported on using graphene and grapehe oxide, synthesized from chemical oxidation of graphite, in manufacturing multifunctional cement based nanocomposites [5-9].

EXPERIMENTAL

Materials

Portland cement (type II) was used as a binder with a specific area of 0.32 m^2/g (blaine fineness). The sand used aggregate had the average particle size of 0.3 mm. The chemical composition of this cement is given in **Table 1**. Pure nanoparticles of graphene and graphene oxide (GraphenExpert, Turkey) were used as the reinforcing materials of cement. The properties of these two nanoparticles are shown in **Table 2**.

Corresponding author: Farani MR, School of Chemical Engineering, University College of Engineering, University of Tehran, Tehran, Postal Code: 4563-11155, Iran, E-mail: m.r.farani@ut.ac.ir

Citation: Farani MR, Ahmadzadeh M, Vahdat A, Barkati M & Ebrahimi SH. (2020) The Effects of Graphene and Graphene Oxide Platelets on Morphology and Mechanical Properties of Cement Mortars. Adv Nanomed Nanotechnol Res, 2(1): 89-92.

Table 1. Chemical composition of Portland cement type II.

Component	Wt%
SiO_2	20.5
CaO	65.00
Al_2O_3	4.6
Fe_2O_3	3.5
SO_3	1.5
MgO	1.5
K_2O	0.5
Na_2O	0.3

Table 2. Properties of the nanoparticles.

Nanoparticle	Number of layers	Purity	Total thickness	BET surface area	BET pore size	Pore volume
Graphene	3-7	>99 wt%	<3 nm	150 m^2/g	134Å	0.5 cm^3/g
Graphene oxide	3-7	>99 wt%	<3 nm	700 m^2/g	78Å	0.34 cm^3/g

Mortars formulation

The mixture components of the mortars are shown in **Table 3**. Mortars were prepared with binder/sand weight ratio (B/S) of 0.36 and water/binder (W/B) of 0.48 according to ASTM-C109. The nanoparticles of graphene (G) and graphene oxide (OG) were replaced by cement and the samples were produced with 0, 0.28, 0.56 and 1.1 wt% G and 0.28, 0.56 and 1.1 wt% percent OG.

Table 3. Mortar formulations.

Samples	W/B	Water (g)	Cement (g)	Sand (g)	Wt% of the nanoparticle
P	0.48	40.33	83.3	229.1	0
G1	0.48	40.33	82.3	229.1	0.28
G2	0.48	40.33	81.3	229.1	0.56
G3	0.48	40.33	79.3	229.1	1.1
GO1	0.48	40.33	82.3	229.1	0.28
GO2	0.48	40.33	81.3	229.1	0.56
GO3	0.48	40.33	79.3	229.1	1.1

Testing procedures

The components were mixed according to Schmidt et al. [10]. On the basis of **Table 3** nanoparticles of G and OG were added to the water separately and the solution was stirred for 15 min. Then the cement was added to the solution and they were mixed at low speed for 30 s. The sand was added to the mixture afterward mixing resumed at high speed for about 30 s. After stopping the mixing process for 2 min, blending the mixture was started again for another 60 s.

The produced mortars were poured into cubic molds with the size of 5 × 5 × 5 mm. An external vibrator was used to facilitate compaction and decrease the amount of air bubbles. The samples were demolded after 24 h and then cured in water at 23 ± 2° for 7 days.

The density of the samples after curing in water for 7 days was measured by Archimedes technique. In order to determine the compressive strength of the samples, compressive test was applied at the speed of 0.9 KN/S.

The morphology of the fracture surface of the samples after compressive test was observed in a scanning electron microscope (SEM, EM-3200).

RESULTS AND DISCUSSION

Mechanical properties

The densities of the samples after 7 days curing in water are given in **Table 4**. The results of the density for both samples containing G and GO particles are close to each other and changing the weight percent of the nanoparticles does not change the density remarkably. But the results of the compressive strength shown in **Figure 1** indicate that a little enhancement in the contents of nanoparticles lead to a great change in the compressive strength of the samples. Unexpectedly, both G and OG had an inverse effect on the compressive strength of the samples. According to rule of mixtures for the composites, it was predicted that the used nanoparticles would increase the compressive strength of the prepared cement mortars. It can be seen that the compressive strength of the OG samples are higher than G samples in all of the cases. This is another unanticipated result that was taken from this experiment.

Table 4. Density of the samples after 7 days curing in water.

Samples	Density
P	2.29
G1	2.29
G2	2.23
G3	2.23
OG1	2.24
OG2	2.21
OG3	2.20

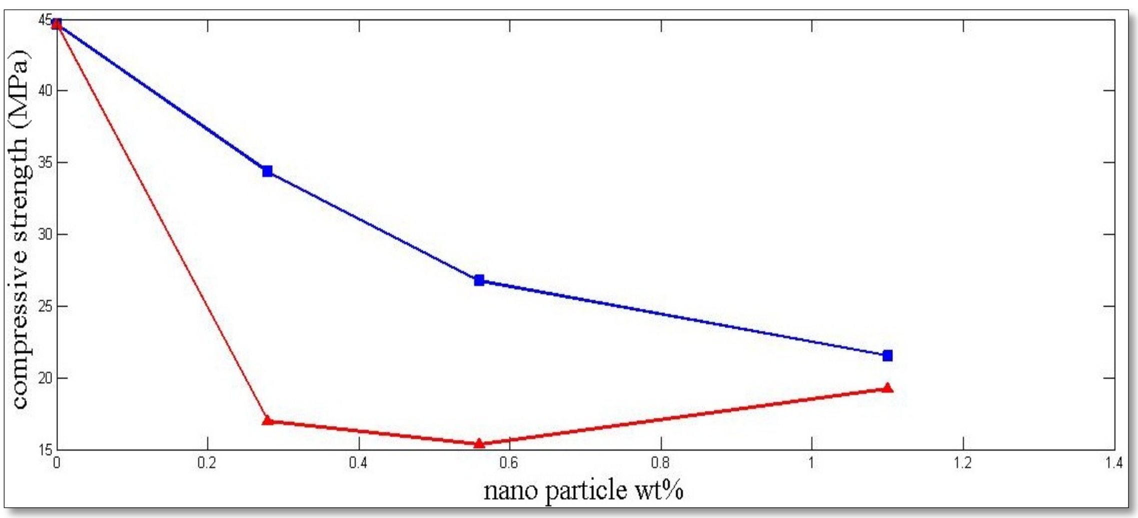

Figure 1. Compressive strength of the samples containing G and GO nanoparticles.

Microstructure

The microstructure of the samples containing G and OG nanoparticles is shown in **Figure 2**. It can be seen that in all the samples, although the particles have been well distributed in the matrix, there is not a good adhesion between the nanoparticles and the matrix. As reported earlier by Pellenq and Van Damme [11] strength of the concrete is originated from hydration process. The main product of the hydration process is a rigid gel called Calcium Silicate Hydrates (C-S-H). This gel is responsible for cohesion and strength of the concrete structures. When nanoparticles of graphene are used in the concrete without functionalizing the surface of the particles, the interfacial strength between C-S-H gel and graphene particles is very low. Alkhateb et al [5] calculated this interfacial strength and they came to conclusion that is it much lower compared to the status of using functional groups on the surface of the graphene nanoparticles. The low compressive strength of the prepared specimens can be directly attributed to the weak connection of cement mortars and dispersed particles. Using suitable functional groups may solve this problem and lead to higher strength. So when using mixture rules in nanocomposites, this unforeseen issue must be taken into account in order to reach to the theoretical results.

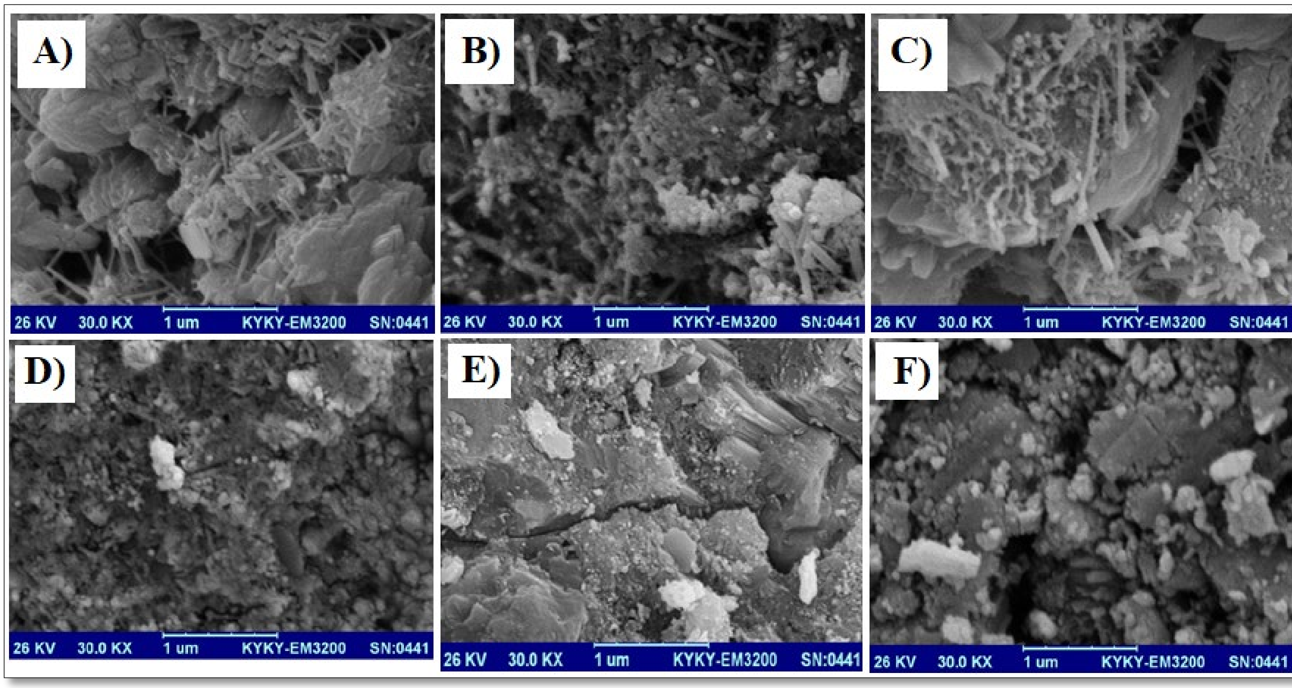

Figure 2. SEM images of the samples: a) G1, b) G2, c) G3, d) OG1, e) OG2 and f) OG3.

CONCLUSION

According to the experiments, using nano graphene and nano graphene oxide in the cement mortars matrix without applying appropriate functional groups on the surface of the platelets will not increase the compressive strength of the concrete because the interfacial strength between nanoparticles and the matrix will be very low. So the failure of the composite will start from the interfacial surface, causing the reduction of the compressive strength of the concrete. Therefore, using suitable functional groups for having higher cohesion is necessary.

REFERENCES

1. http://www.nsf.gov/
2. Lau KTA, Hui D (2002) The revolutionary creation of new advanced materials-carbon nanotube composites. Composites Part B 33: 263-277.
3. Leydecker S, Kölbel M, Peters S (2008) Nanomaterials in architecture, interior architecture and design. Birkhäuser, Berlin.
4. Li H, Xiao H, Yuan J, Ou J (2004) Microstructure of cement mortar with nanoparticles. Composites Part B 35: 185-189.
5. Alkhateb H, Al-Ostaz A, Cheng AHD, Li X (2013) Materials genome for graphene-cement nanocomposites. J Nanomech Micromech 3.
6. Liu C, Yu Z, David N, Aruna Z, Jang BZ (2010) Graphene-based supercapacitor with an ultrahigh energy density. Nano Lett 10: 4863-4868.
7. Zhang LL, Zhao S, Tian XN, Zhao X (2010) Layered graphene oxide nanostructures with sandwiched conducting polymers as supercapacitor electrodes. Langmuir 26: 17624-17628.
8. Zhang K, Zhang LL, Zhao XS, Wu J (2010) Graphene/polyaniline nanofiber composites as supercapacitor electrodes. Chem Mater 22: 1392-1401.
9. Yan J, Wei T, Shao B, Fan Z, Qian W, et al. (2010) Preparation of a graphene nanosheet/polyaniline composite with high specific capacitance. Carbon 48: 487-493.
10. Schmidt M, Fehling E, Glotzbach C, Fröhlich S, Piotrowski S (2012) Ultra-high performance concrete and nanotechnology in construction. Proceedings of Hipermat 2012. 3rd International Symposium on UHPC and Nanotechnology for High Performance Construction Materials, Kassel, March 7-9, 2012.
11. Pellenq RJM, Van Damme HV (2004) Why does concrete set? The nature of cohesion forces in hardened cement based materials. MRS Bull 29: 319-323.