Features of Cement Composites with Carbon Nanostructures

T.G. Makeeva[1], *A.Ya. Khavkin*[2]
[1]*Lomonosov Moscow State University, Moscow, Russia*
[2]*Gubkin Russian State University of Oil and Gas (National Research University), Moscow, Russia*

Abstract. In this article we deal with the influence of carbon nanostructures on the strength properties of cement composites. Introduction of dispersed additives in the form of single-walled and multi-walled carbon nanotubes into composites based on cement and soil of different dispersion and similar genesis allows improving their mechanical properties. Increasing the number of spin-polarized electrons in associated water and reducing pore size contributes to the effective modification of cement composites with carbon nanostructures. With increasing dispersion of polymineral soil at the optimal concentration of carbon nanotubes, film thickness of new formation and its binding energy in the composite increases. Modification of cement composites with carbon nanostructures increases their strength depending on dispersion of their constituents, content and structure of carbon nanotubes.

Keywords: cement, soil, composite, dispersion, structure, carbon nanotubes, strength
DOI: 10.18599/grs.18.1.10

For citation: Makeeva T.G., Khavkin A.Ya. Features of Cement Composites with Carbon Nanostructures. *Georesursy* [Georesources]. 2016. V. 18. No. 1. Pp. 55-57. DOI: 10.18599/grs.18.1.10

Methods of intensification of oil production play a huge role in improving oil recovery. The most important group of these methods includes technical methods such as hydraulic fracturing, different types of perforation, sidetracking and others (Khavkin, 2010). In all these methods, the basis for the effective implementation is the strength properties of the casing cement stone.

One of the disadvantages of composites based on Portland cement is a low resistance to cracking. Studies have shown that the strength of cement can be increased by adding into cement mortar of homeopathic doses of carbon nanostructures of carbon nanotubes (CNTs): the introduction of nanosized carbon additives (including carbon nanotubes) in the composite concrete structure reduces cracking and increase the strength of concrete performance through load transmission from cement stone to high strength and elastic CNTs (Khavkin, 2010; Coleman et al., 2006; Tkachev et al., 2007; Akhmeshina, Kodolov, 2010).

Preliminary we together with a number of colleagues (Makeyev et al., 2015) studied properties of CNTs. Composite materials based on cement supplemented with CNTs were produced by standard methods in special cylindrical molds with a diameter of 1.65 cm^2, sealing with pressure of 3 MPa, at a water-cement ratio W/C = 1.8, density 1.8 g/cm^3. Formed composites were stored in humid air environment. For the study we selected polymineral soils of different particle size of fluvioglacial genesis films. Thus SMS 90 SB cement additives were used in the amount of 10%. Tests on the uniaxial compression of samples were carried out using the device P-12 and IM-P4 according to standard procedures (Trofimov, Korolev, 2008). As nanostructured additives for cement multilayer and monolayer-euglerodnye nanotubes were used in the amount of 0.01-0.1% by weight, in the dry method of introduction (Khavkin, 2010; Akhmeshina, Kodolov 2010, Makeyev, 2015).

Cement composite mixtures are energetically heterogeneous systems and have a high concentration of electrons and spin-polarized electrons (bound water). It allows us to adjust their charge and spin electronic states, which is the basis for the development of composite materials with desired properties. Prospect of approaches that use CNT ultrafine particles to create composite materials based on cement is based on the fact that at the atomic level we can affect the cement bound water film, thus changing the reactivity of the composite components. In this regard, in cement composites with CNT dispersion role increases of structural and mineral characteristics with all other conditions being equal.

The impact of CNTs on the structure of composite materials essentially depends on their properties. The cement composites with more fine-grained soil a large number of new formations appears compared to less fine-grained soil, with all other conditions being equal. Increasing the number of spin-polarized electrons of bound water and reducing pore size contributes to the effective modification of cement composites with carbon nanostructures. This is due to additional elements of the composite reinforcement and coordination of interaction of water with film cement minerals. Thus there is convergence of the particles and decrease of the pore space, resulting in a change of the composite structure.

Structural and textural features based on cement composites with different types of ground-based and carbon additives are determined by composite component, the size and morphological features of the constituent elements, their spatial arrangement and the nature of their interaction with neoplasms. When the CNTs content from 0.01% to 0.1%, their activity is reduced, as well as the effect of increasing strength properties, which is likely due to the disruption of the hydration process of cement clinker minerals, as well as increasing the role of micro-defects in the amount of CNTs.

Naturally, in the process of creating concrete using different soils as a structure-forming element, an important role is played by a film adsorbed on the surface of the quartz sand particles (Rakhimbaev et al., 2014).

Studies have shown that the effectiveness of the impact of carbon nanostructures on the film of polymineral soils with different dispersion is exponential dependence from the crystal-film heterogeneous surface and increases in the series: Siliceous> ferruginous> illite> smectite.

In the same sequence, depending on the dispersion and the soil, exchange capacity increases.

The major role of soil nanocomponents in their structural and filtration properties is shown in (Izotov, Sitdikova, 2007). Our studies have shown that with the same content of additives multilayer carbon nanotubes with matted fibrous disordered microstructure are most effective as compared with the single-layer carbon tubes with a pseudo-globular ordered microstructure when choosing dry introduction into composite.

Study of cement composites with CNT microstructures based on soils of different dispersion showed that the composites with the same content of CNTs but different in dispersed soils have different structures (Fig. 1, 2).

Our research on strength of cement composites based on soils with different content of clay fraction (3% – sand silty; 10% – sandy loam solid; 15% – sandy loam plastic; 20% – light loam, 25% – loam heavy) have shown that the greatest strength is achieved at some intermediate value of multilayer

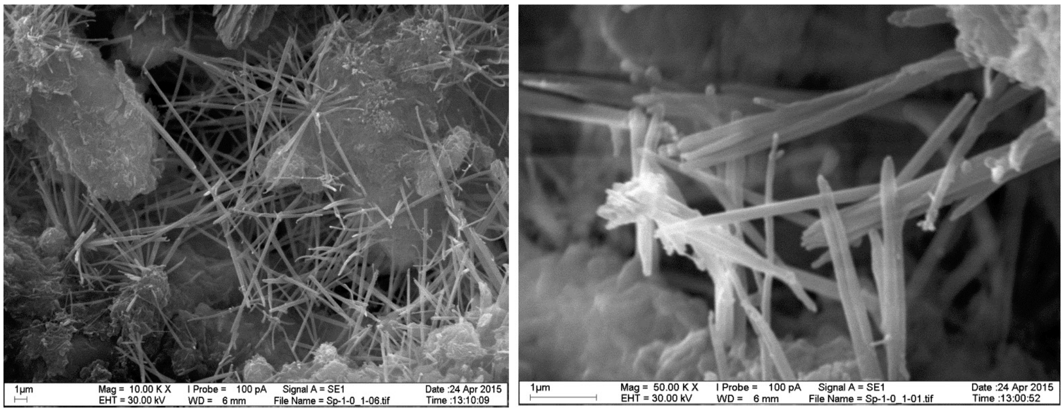

Fig. 1. Closely packed and netted microstructure of the composite cement with matted-fibrous, non-ordered structure of multilayer CNTs based on silty sand (on the left – increase 10.0KH, on the right – 50.00 KH, photo by M.S. Chernov).

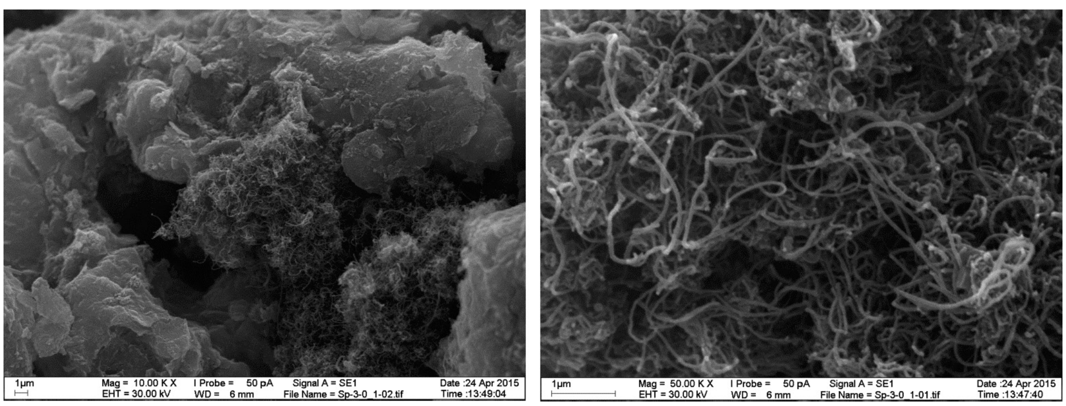

Fig. 2. Closely packed microstructure with matted-fibrous, non-ordered structure of multilayer CNTs based on heavy loam (on the left – increase 10.0KH, on the right – 50.00 KH, photo by M.S. Chernov).

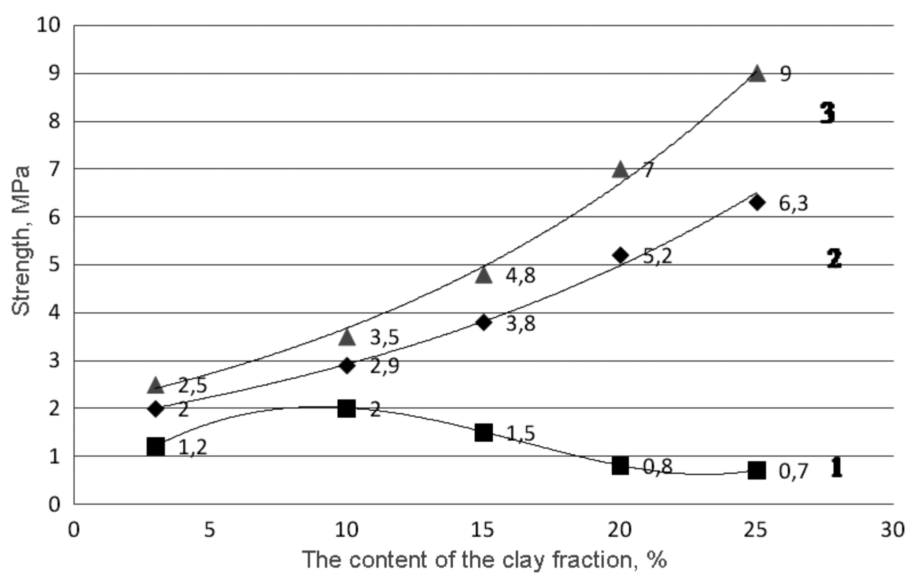

Fig. 3. Change in the strength of cement composites based on soils of different dispersion, depending on the content of the clay fraction with the content of multilayer CNTs: 1 – 0%; 2 – 0.1%; 3 – 0.01%.

CNTs in the range of 0-0.1% (around 0.01%) at any type of cement forming soils (Fig. 3).

Thus, the introduction of dispersed additives in the form of single-layer carbon nanotubes and multilayer composites based on cement and soil of different dispersion and single genesis improves their mechanical characteristics. Increasing the number of spin-polarized electrons of bound water and reducing pore size contributes to the effective modification of cement composites with carbon nanostructures. With the increase of dispersion of polymineral soil at the optimum concentration of carbon nanotube, new formations film thickness and its binding energy in the composite increases.

References

Akhmeshina L.Yu., Kodolov V.I. Features of modification technology of concrete compositions with carbon metal-containing nanostructures. *Materialy II Mezhd. nauch.-prakt. konf. «Nanoyavleniya pri razrabotke mestorozhdeniy uglevodorodnogo syr'ya: ot nanomineralogii i nanokhimii k nanotekhnologiyam»* [Proc. II Int. Sci. and Prac. Conf. «Nanophenomena during hydrocarbon development: from nanomineralogy to nanochemistry and nanotechnology»]. Moscow: Neft' i gaz. 2010. Pp. 384-388.

Coleman J.N., Khan U., Blau W.J., Gunko Y.K. Small but strong: a review of the mechanical properties of carbon nanotube-polymer composites. *Carbon*. 2006. V. 44. Pp. 1624-1652.

Izotov V.G., Sitdikova L.M. Nanomineral systems of oil reservoir and their role in development process. *Georesursy* [Georesources]. 2007. № 3. Pp.21-23. (In Russ.)

Khavkin A.Ya. Nanoyavleniya i nanotekhnologii v dobyche nefti i gaza [Nanophenomena and nanotechnologies in oil and gas production]. Moscow: IIKI. 2010. 692 p.

Makeeva T.G. Struktura, morfologicheskie osobennosti i svoystva gruntovykh kompozitnykh materialov na osnove tsementa raznogo sostava [The structure, morphological features and properties of soil composite materials based on cement of various compositions]. *Gruntovedenie* [Soil Science]. 2015. № 2. Pp.26-39.

Makeeva T.G., Khavkin A.Ya., Egorov Yu.M. et al. Osobennosti svoystv uglerodnykh nanotrubok [Features of carbon nanotubes properties]. *Estestvennye i tekhnicheskie nauki* [Natural and Technical Sciences]. 2015. № 11. Pp. 491-499.

Rakhimbaev Sh.M., Tolypina N.M., Karpacheva E.N. Rol' plenok, adsorbirovannykh na poverkhnosti chastits prirodnogo kvartsevogo peska, v protsessakh plastifikatsii betonnykh smesey [Role of films adsorbed on the surface of a natural quartz sand in concrete mixed plastifying processes]. *Promyshlennoe i grazhdanskoe stroitel'stvo* [Industrial and civil construction]. 2014. Pp. 15-18.

Tkachev A.G., Mikhaleva Z.A., Ladokhina M.N., Zhutova E.A. Modifitsirovanie stroitel'nykh kompozitov uglerodnymi nanomaterialami [Modifying of construction composites by carbon nanomaterials]. *Energetika* i ekologiya [Energy and Ecology]. 2007. № 9. Pp. 56-59.

Trofimov V.T., Korolev V.A. Laboratornye raboty po gruntovedeniyu [Laboratory work on soil science]. Moscow: Vysshaya shkola. 2008. 518 p.

Information about authors

Tamara G. Makeeva – PhD, Senior Researcher, Geological Faculty, Lomonosov Moscow State University

Russia, 119234, Moscow, Leninskie gory, 1

E-mail: makeeva13new@yandex.ru

Aleksandr Ya. Khavkin – Doctor of Science, Director of the Scientific Center of Russian Nanotechnological Society, Professor, Gubkin Russian State University of Oil and Gas (National Research University)

Russia, 119991, Moscow, Leninsky prospekt, 65

E-mail: aykhavkin@yandex.ru

Received February 04, 2016