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Increased durability concrete for generation of pillars power lines

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Abstract. In this researches multilayered carbon nanotubes of production of the French corporation "Arkema" were used. It has followed features: diameter of 10-15 nanometers and up to 15 microns long. Multilayered carbon nanotubes were used for increasing of physics and technology properties of cement concrete. It was established that at introduction of multilayered carbon nanotubes in amount of 0.006% of the mass led concrete durability increases by 28%, resistance to frost from F200 to F400, tightness to water from W8 to W14.

Despite keen interest of Russian and foreign researchers in nano-modification technology, many experts are skeptical about the hypotheses describing the mechanism of cement stone structure formation in presence of nanometer-sized carbon particles [1, 2]. One of the main reasons for skepticism about the impact of carbon nanotubes (CNTs) on the structure and properties of cement matrix is their incomplete dispersion in liquid phase.

Due to high surface energy the CNTs form globules during synthesis, the globules size ranges from 400 to 900 microns. The nanotubes are poorly distributed in aqueous medium and require special techniques for their dispersion [3-5]. The problem is not only to disintegrate the initial globules, but also to prevent CNTs coagulation process in water-dispersion system during storage.

Typically, CNTs are dispersed by prolonged mechanical grinding of initial product. However, there is a certain limit of dispersion due to the laws of thermodynamics, since the system tends to reduce free energy, which becomes apparent in reverse aggregation of particles [6-8]. Thus, a crucial technological problem is to disaggregate carbon nanotubes and to distribute them uniformly in concrete mix.

The studies [9-10] conducted in the Kalashnikov ISTU showed a significant improvement in physical and technical properties of concretes modified with carbon nanotubes. It was found [11] that such concretes had better strength, frost resistance and waterproof capacity when modified. All these parameters are crucial for the construction of reinforced concrete poles used for power lines.

Traditional concrete formulations do not provide necessary durability because of deterioration of, first of all, concrete reinforcement protective layer (Fig. 1).

Durability of reinforced concrete poles was increased by modifying cement concrete with multilayer carbon nanotubes Graphistrength Masterbatch CW2-45 (MCNTs) produced

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by the French corporation "Arkema". To disperse the MCNTs a high-speed bead mill developed Novy dom LLC (Izhevsk city) was used. Currently CNTs dispersion is performed under Fulvec 100 trade name.

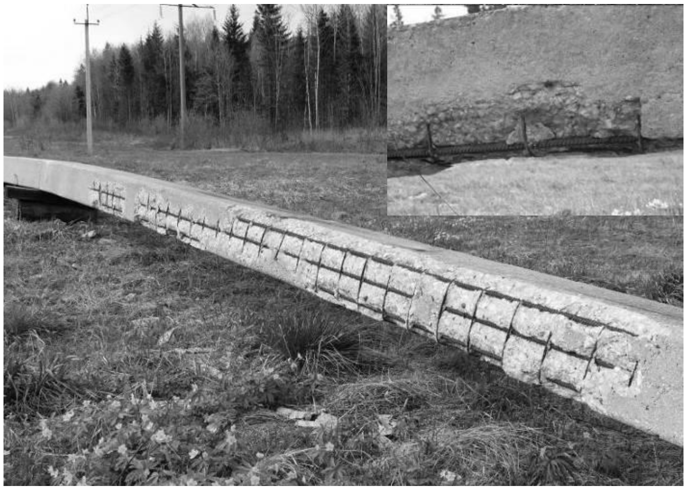


Fig. 1. Deterioration of reinforced concrete power line pole protective layer by frost (a fragment of the exposed reinforcement cage is shown in the upper corner).

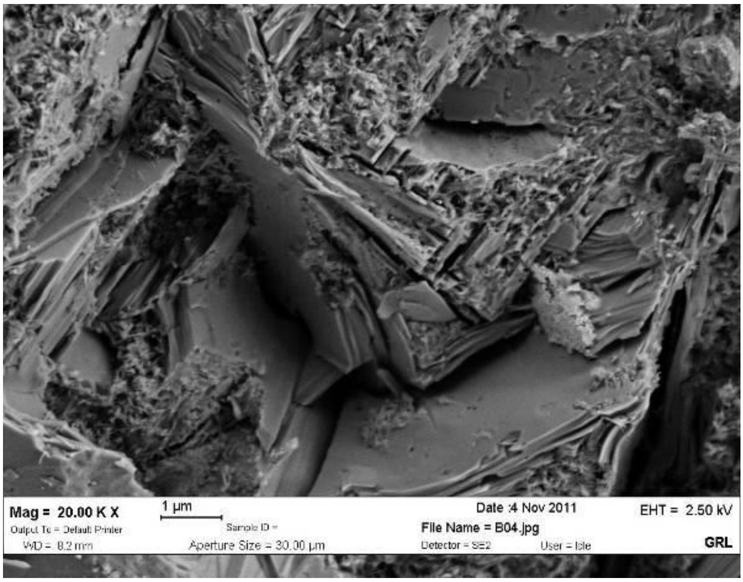
Usage of the Graphistrength Masterbatch CW2-45 dispersion with 2% content of the MCNTs prepared in the bead mill ("Dispersion 2-BM") with B-30 heavy concrete in the amount of 0.006% of Portland cement weight allowed to increase samples strength by 28% (Table 1).

Table 1. Results of testing B-30 heavy concrete cube samples added with 2% CNTs Graphistrength Masterbatch CW2-45 dispersions on the 28th day under normal curing conditions and on the 1st day after steam curing.

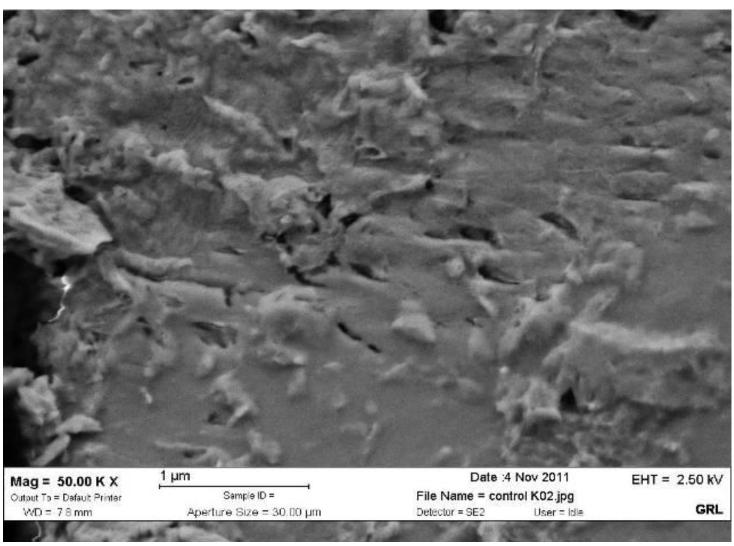
Samples marking	Avg. strength, R_{28}^{c}, MPa	Relative change in strength, %
Reference sample (normal curing conditions)	54.1	-
Added with the "Dispersion 2-BM" (normal curing conditions)	69.3	+28.1
Reference sample (after steam curing)	36.4	-
Experimental sample added with the "Dispersion 2BM" (after steam curing)	41.8	+14.8

Usage of the MCNTs dispersion results in structural changes of cement stone involving formation of dense skin on the surface of solid phases, including cement and filler particles. Contact interactions of structured boundary layers result in formation of spatial frame cells in a modified cement matrix with dense layers of crystalline hydrates. This leads to hardening of the entire modified cement matrix.

High density hydrated calcium silicate-based spatial frame predetermines its greater strength, which leads to higher frost resistance of cement stone in concrete mixture (Fig. 2).



a)



b)

Fig. 2. Fragment of B-30 heavy concrete reference sample surface microstructure after frost resistance test corresponding to F200 grade at 50,000x magnification (a); fragment of sample surface microstructure added with the CNTs after frost resistance test corresponding to F400 grade at 20,000x magnification (b).

CNTs-modified heavy concrete frost resistance test (strength class B-30) showed frost resistance increasing from F200 to F400 (Fig. 2b).

Concrete waterproof capacity is one of the most important parameters affecting its durability.

According to the tests, the reference samples concrete grade by waterproof capacity was W8. Experimental samples made of modified concrete were tested up to 7th stage inclusive at water pressure of 1.4 MPa. No water filtration signs in the form of drops or a wet spot on the upper end surface of the sample were observed. According to the tests, the experimental samples concrete grade by waterproof capacity was W14.

Increasing the grade by waterproofing capacity in experimental samples with the same cement-water ratio, subject to compliance with test procedure, confirms the assumption of a smaller number of interconnected micropores and capillaries making concrete permeable.

Pilot testing of the modifying CNT additive was performed in production of SV-95-3(CB-95-3a) a reinforced concrete pillars for power line VL 0.4–10 kV poles. Bench tests were performed at Reinforced Concrete Products Plant LLC (Izhevsk city). The poles were made of B-30 concrete in accordance with Specification 5863-007-00113557-94 using working drawings of 3.407.1-143 series standard structures. Basic parameters obtained during testing of SV-95-3a (CB-95-3a) reinforced concrete pillars for power line VL 0.4 – 10 kV poles are shown in Table 2.

Table 2. Results of factory tests of the SV-95-3-a reinforced concrete pillars for power lines VL 0.4 – 10 kV.

Stage No.	Load, kgf	Holding time, min.	Actual bending, mm		Width of cracks opening, mm		Requirements of the Specification 53163-007-00113557-94 by strength, hardness, cracks resistance
			with CNTs	without CNTs	with CNTs	without CNTs	
1	100	10	26	35	not found	not found	-
2	250	10	92	103	not found	cracks less than 0.05	-
3	330	30	142	162	cracks less than 0.05	cracks less than 0.05	cracks are ≤0.05 mm
4	400	30	167	195	cracks of 0.05	cracks of up to 0.1	bending is ≤ f=400 mm
5	500	10	237	277	cracks of up to 0.1	cracks less than 0.15	-
6	560	30	292	348	cracks of up to 0.15	cracks of up to 0.15	no deterioration, bending is ≤ f = 400 mm, cracks are ≤ 0.15 mm

The tests showed that the SV 95-3a (CB 95-3a) reinforced concrete pillars of the VL 0.4...10 kV poles made of heavy concrete modified with the CNTs dispersion comply with the Specification 53163-007-00113557-94 by strength, hardness and cracks resistance. A decrease in bending of the reinforced concrete pillars with the CNTs by 20% on the average in comparison with the reference products made of concrete without modification was also noted.

Economic efficiency calculation showed that with the increase in market value of the SV-95-3a (CB-95-3a) reinforced concrete pillars by 5.0% due to modification with carbon nanotubes, their service life will increase by at least 8 years due to increased durability. The economic effect of concrete modification will be 40% of the cost of a reinforced concrete pillar made without the use of the modifying additive.

References

1. I.A. Pudov, A.V. Pislegina, A.A. Lushnikova, G.N. Pervushin, G.I. Yakovlev, O.L. Khasanov, A.A. Tulaganov, The II International Conference NTC-2010 “Nanotechnology for green and sustainable construction”, 34-38 (2010)
2. B.S. Sindu, S. Sasmal, S. Gopinath, Construction and Building Materials **50**, 317-327 (2014)
3. A. Sobolkina, V. Mechtcherine, V. Khavrus, D. Maier, M. Mende, M. Ritschel, A. Leonhardt, Cement & Concrete Composites **34**, 1104-1113 (2012)
4. A. Sobolkina, V. Mechtcherine, C. Bellmann, V. Khavrus, S. Oswald, S. Hampel, A. Leonhardt, Journal of Colloid and Interface Science **413**, 43-53 (2014)
5. O. Mendoza, G. Sierra, J.I. Tobyn, Construction and Building Materials **47**, 771-778 (2013)
6. B. Wang, Y. Han, S. Liu, Construction and Building Material **46**, 8-12 (2013)
7. I.A. Pudov, G.I. Yakovlev, A.A. Lushnikova, O.V. Izryadnova, Intelligent Systems in Production **2**, 285-293 (2011)
8. G.D. Fedorova, A.E. Savvina, G.I. Yakovlev, I.S. Maeva, S.A. Senkov, Construction Materials **2**, 48-54 (2013)
9. G.I. Yakovlev, S. Soliman, G.N. Pervushin, I.A. Pudov, M. Saber, Construction Materials **11**, 3-5 (2011)
10. G. Yakovlev, G. Pervushin, I. Maeva, Ja. Keriene, I. Pudov, A. Shaybadullina, A. Buryanov, A. Korzhenko, S. Senkov, Procedia Engineering **57**, 407-413 (2013)
11. A. Korzhenko, M. Havel, P. Gaillard, G.I. Yakovlev, G.N. Pervuchin, D.V. Oreshkin Procede D’introduction de nanocharges carbonees dans un inorganique durcissable. Patent № 2 969 143. C 04 B 16/12 (2012.01), C 04 B 28/00. Bulletin 12/25 pub. 22.06.12

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