

Nanomodification of cement systems as an effective way to improve the quality of special-purpose mortars

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ABSTRACT

The paper presents the results of a study of the performance properties of waterproofing solutions modified with unpurified carbon nanotubes (CNTs). Water absorption was assessed on samples of expanded-clay concrete and heavy concrete. It was found that the introduction of unpurified CNTs reduces water absorption by 22% - 46% compared to the control composition of the waterproofing solution, which confirms the effectiveness of nanomodification for increasing the water resistance of concrete structures. In addition, it was found that the addition of unpurified CNTs to the concrete composition contributes to an increase in strength characteristics by almost 40% [1,2,3].

Keywords: waterproofing, carbon nanotubes, nanomaterials, nanotechnology.

1. INTRODUCTION

Waterproofing of concrete structures is an important factor in ensuring their durability and reliability of operation. In recent years nanotechnology has become increasingly popular for improving the characteristics of building materials. Of particular interest is the introduction of unpurified carbon nanotubes (CNTs) as a modifier that can improve the microstructure and reduce the water permeability of waterproofing solutions. In most recent global studies, CNTs were added to concrete to improve its strength characteristics (compressive strength, flexural strength), which were significantly increased after the introduction of CNTs (up to 40%) [1,2,3].

In this work it was decided to focus on the study of water absorption of penetrating waterproofing modified with unpurified CNTs, in contrast to the widespread studies of strength characteristics of concrete.

Carbon nanotubes are nanomaterials and are elongated cylindrical structures with a diameter of one to several tens of nanometers and a length of one micron to tens of microns. They consist of one or more hexagonal graphite planes (graphenes) rolled into a tube.

For this study, carbon nanotubes manufactured by the Institute of Gas of the National Academy of Sciences of Ukraine were used.

2. OBJECTIVE

The objective of the study is to develop principles for the compositional construction of nanomodified special-purpose building mortars, as well as to assess the effect of adding unpurified carbon nanotubes on the water absorption of waterproofing mortars in order to improve their performance properties.

3. INFLUENCE OF NANOTUBES ON WATER ABSORPTION

Measurements of the effect of nanotubes on water absorption were carried out on two types of waterproofing

coating (control composition and modified with unpurified CNTs), which were applied to samples of lightweight (expanded-clay concrete) and heavy concrete.

3.1. Preparation of nanotubes dispersion

In world practice, several methods of mechanical dispersion of nanotubes are adopted: mechanical mixing (using a dissolver, etc.), ultrasonic dispersion, and cavitation dispersion. One of the most common methods is ultrasonic dispersion, when nanotube clusters are destroyed under the action of ultrasound, which contributes to their homogenization in solution.

Based on previous studies [4], it is known that in order to introduce and evenly distribute the CNTs throughout the volume of cement compositions, it is advisable to disperse the carbon nanotubes in a plasticizer (of various types: polycarboxylate, lignosulfonate, melamine formaldehyde).

When conducting these studies, the unpurified CNTs were dissolved in the superplasticizer Sikaplast-520 (concentration of 1% nanotubes by weight of the plasticizer) using an ultrasonic disperser (UZDN A 1200) for 10 minutes until a homogeneous dispersion was formed.

3.2. Preparation of concrete samples

Samples of two types of concrete were formed (expanded-clay concrete with the following composition: P/C 20%, quartz sand 57%, expanded-clay gravel 23%, W/C ratio 0.4; heavy concrete with the following composition: P/C 14%, quartz sand 29%, granite rubble 57%). The hardening of the concrete samples and the acquisition of strength occurred under normal conditions (temperature 20±2°C, relative humidity 95±5°C) for 28 days.

The strength of the concrete was measured on days 2, 7 and 28 of curing. The results are given in Table 1.

Table 1: Results of physical and mechanical tests of concrete

Type of concrete	Strength, MPa					
	day 2		day 7		day 28	
	fs	cs	fs	cs	fs	cs
1	5,0	34,8	7,1	44,8	7,2	56,6
2	0,8	6,0	2,0	15,0	4,0	25,0

where 1 – heavy concrete, 2 – expanded-clay concrete, f_s – flexural strength, cs – compressive strength.

3.3. Applying waterproofing

The following components were used for the control waterproofing composition: P/C (23.75%), slag (10.12%), zeolite (1.78%), Na_2SO_4 (2.00%), Na_2CO_3 (1.60%), $NaNO_3$ (0.40%), sand (60.35%). The control composition was modified with unpurified carbon nanotubes by adding a dispersion of the plasticizer Sikaplast-520 with dissolved unpurified CNTs (in an amount of 1% by weight of P/C).

The control waterproofing composition was prepared as follows: water was added to the dry waterproofing mixture (water consumption 0.4, cone spread 220 mm). The waterproofing was applied to one side of the concrete sample (layer thickness 2-3 mm).

The modified waterproofing composition was prepared as follows: a dispersion of plasticizer and unpurified CNTs was added to the dry waterproofing mixture, water was added (W/C ratio 0.4, cone spread 220 mm). The waterproofing was applied to one side of the concrete sample (layer thickness 2-3 mm).

3.4. Water absorption measurement

Based on the conducted studies, it can be concluded that currently there is no single method for measuring water absorption. Generally, the methods for preparing waterproofing solutions and further measurement of water absorption differ from each other and depend on the recommendations of a particular manufacturer.

In this study, the following measurement technique was used: waterproofing was applied to concrete samples, after which the waterproofing was allowed to dry completely (within 1 day). Next, the concrete sample with the dried waterproofing coating was immersed in water for 3 days. Then the samples were removed from the water and allowed to dry for another 3 days. After that, water absorption was measured using Karsten tubes for 4 and 24 hours. The Karsten tube was installed on the concrete sample on the face covered with the waterproofing solution, and the tube was fixed hermetically with paraffin. After that, water was poured into the tube and the amount of water absorbed by the concrete samples during a given time was measured.

3.5. Water absorption coefficient

The calculation of the water absorption coefficient was performed using the formula (1).

$$R = (m_2 - m_1) / F \cdot vt, \quad (1)$$

where m_2 – mass of water-saturated sample, kg; m_1 – mass of dry sample, kg; F – sample area, m^2 ; t – immersion time, hours.

4. RESULTS

After conducting the experiments, the following results were obtained: when adding unpurified CNTs to the waterproofing solution, its water absorption decreased by 22% - 46% compared to the waterproofing solution of the control composition (without unpurified CNTs), while the water absorption coefficient decreased almost by two times (by 1.7 times for expanded-clay concrete and by 1.8 times for heavy concrete). The results are given in Table 2.

Table 2: Results of water absorption measurements of waterproofing solutions applied to heavy and lightweight concrete

Concrete type	Measurement time, hours	Waterproof, composition	Water absor., ml	Water absor. coeff.
1	4	Control	27	
1	4	with CNTs	21	
Diff., %			-22%	
1	24	Control	60	0.29
1	24	with CNTs	36	0.17
Diff., %			-40%	
2	24	Control	46	0.22
2	24	with CNTs	25	0.12
Diff., %			-46%	

where 1 – expanded-clay concrete, 2 – heavy concrete.

5. CONCLUSIONS

Therefore, by analyzing the obtained data, it can be concluded that the introduction of unpurified CNTs into waterproofing solutions contributes to a reduction in the water absorption coefficient by almost 2 times, which indicates the need for further research aimed at determining the best dispersion methods, the use of nanotubes of various degrees of purification, determining the degree of homogenization in different types of plasticizers, as well as studying the influence of nanotubes concentration (based on the mass of the plasticizer) on the performance properties of waterproofing solutions.

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