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Radioprotective materials with tungsten nanopowder additives

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Abstract. There’s been studied influence of submicron powder additives obtained by processing hardmetal waste ТТК (TiC-WC-TaC-Co), on strength properties of cement. This modified cement is used as a structural material for containers at transportation and storage of radioactive waste.

1. Introduction
Safe handling of radioactive waste includes secure insulation which gives safety both to environment and human health during the whole period of radiation hazard. Safe handling is achieved by a system of physical barriers on the way of ionizing radiation and radioactive substance in the environment. One of these barriers is package for radioactive waste [1].

Design and constructional material of a container being an element of the packaging must ensure its structural integrity and operability while handling the package for radioactive waste [2].

In recent years various concrete containers have been used for this purpose. These containers have become an alternative to metal containers widely used previously. Concrete is famous for its good radioprotective properties and resistance to external factors [3].

But over time, changes occurring during storage of the waste have an influence on their migration properties and defense capability of physical barriers [4]. Therefore in the present moment increase in strength and therefore durability of concrete materials used for containers’ production in compliance with necessary technical regulations remains a topical problem, especially in radioactive waste handling. This problem could be successfully solved by using various additives at the manufacturing stage.

One of the promising directions in improving properties of construction materials based on concrete to produce radioactive waste storage containers is nanomodifiers which allow increasing significantly strength properties of the material. However, now their large-scale application in the construction industry is minimal. This is due to the cost of nanopowder and its low volume of production that doesn’t meet the industry demand.

This paper continues with the papers [5-9]. Previous studies have shown that production of nanopowder by the proposed method can significantly reduce its cost, as well as to increase production to quantity required for the industry due to modularity of the technological cycle.

The aim of this paper is to study ability to modify concrete by submicron size powder.

To succeed in it we’ve tried to make the following:
– to analyze elemental and granulometric composition of the powder being an additive to concrete;
– to study strength properties of concrete modified with the powder;
to determine an optimal concentration of modifiers for concrete.

2. Experimental part
Concrete is a complex composite material consisting of sand, coarse aggregate (crushed stone and other materials), cement and water [10]. Cement paste (cement and water) fills all the voids in the sand, covering its particles with a thin layer. Cement-sand mortar fills in its turn all the voids in the coarse aggregate, which forms a rigid spatial structure inside the product.

Strength of concrete depends in many ways on strength and quality of a coating solution. Therefore, this paper deals with changes of ultimate strength in modified concrete without coarse aggregate added.

To study changes in concrete strength properties we applied materials widely used in construction (table 1).

Table 1. Source materials.

| Material         | Brand             | Specifications and technical documentation          |
|------------------|-------------------|-----------------------------------------------------|
| Portland-cement  | PC II/A–SH–400    | Specification BV.2.7–46-96                          |
| Bank sand        | 1,9 – 2,2 mm fraction | State Standard 8736–93                      |

A mixture of titanium carbide, tungsten carbide and tantalum carbide, obtained by waste processing, was used as a concrete modifier.

Qualitative and quantitative composition analysis of the powder being a modifier was made using ElvaX Light spectrometer (see table 2).

Analysis of granulometric composition of modifiers with the laser particle-size analyzer “Analisette 22 NanoTec” is shown in figure 1.

The samples obtained were subjected to destruction by the standard procedure using UM machine – 5.

Table 2. The powder – modifier’s elemental composition.

| At. number | Element | Content, % |
|------------|---------|------------|
| 42         | Mo      | 0.036      |
| 26         | Fe      | 0.071      |
| 20         | Ca      | 0.211      |
| 41         | Nb      | 1.587      |
| 14         | Si      | 2.009      |
| 27         | Co      | 4.560      |
| 73         | Ta      | 5.076      |
| 22         | Ti      | 7.821      |
| 74         | W       | 78.629     |

It is found that percentage of the particles depending on size is as follows (figure 1): up to 500 nm - about 30 %, 500 nm –1 micrometer – 70%. This calculation model shows a ratio of length to diameter of the particles in the range of 1,441 to 2,495.
The sample of sanded concrete was a mixture of portland-cement PC II / A–SH–400 (table 1) and sifted river sand in 1:3 and 1:2 ratio. The powder was used as a modifier in various concentrations (1, 3, 5, 7, 9, 10 wt.%). The resulting mixture was stirred in a tumbling drum for 15 minutes, and then water was gradually added while stirring until the required solution consistency was reached. The resulting cement-sand mortar was poured into a mold (18x18x16 mm) and allowed to cure at the temperature of 20–25 °C for 28 days.

The obtained samples were subjected to destruction using standard procedures. The results are presented in figure 2.

As it is known, increasing cement fraction in the solution results in increased strength. In fact, modifier’s influence on cement matrix strength (figure 2) is most pronounced at low ratio of cement to sand (1:3). The optimal powder concentration is 1% that increases material’s ultimate strength by 222%.
The more the cement fraction the less influence of the modifier (figure 3). The optimal cement fraction is 2 % that gives an increase in ultimate strength by 32 %.

In our opinion, increase in strength properties of sanded concrete by adding modifiers of submicron size is related to formation of microcracks and residual microporosity. Powder additives form structure types which are certain traps for developing cracks under load. This assumption requires further research.

3. Conclusion
There’s been analyzed elemental and granulometric composition of the powder used as modifiers for sanded concrete. There’s been proven modifier’s influence on increase of strength properties of sanded concrete. The optimal concentration of modifiers is found to be 1 %, with increase in strength in more than 2 times.

The observed effects can be used in creation of new structural materials for radioprotective material production (storage containers or radioactive waste transporting equipment).

In the future we expect to study the obtained samples for increase of their radioprotective properties and durability.

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