PROCEEDINGS OF THE INTERNATIONAL CONFERENCE NANOMATERIALS: APPLICATIONS AND PROPERTIES
Vol. **1** No 3, 03AET09(3pp) (2012)

Super Heavy Nano Reinforcing Concrete

A.A. Smolikov[1,*], V.I. Pavlenko[1], V.M. Beresnev[2], D.A. Kolesnikov[3], A.S. Solokcha[1]

[1] *Belgorod Shukhov State Technological University, 308012 Belgorod, Russia*
[2] *Kharkov Karazin State University, 61077 Kharkov, Ukraine*
[3] *Belgorod State University, 308015 Belgorod, Russia*

(Received 20 July 2012; published online 26 August 2012)

The properties of modern heat resistant super heavy concrete reinforced by chrysotile nanotubes are described.

Keywords: Quick nuclear reactors, Super heavy concrete for biological protection, Chrysotile nanotubes, Reinforcement.

PACS numbers: 61.48.De, 61.46.Np, 43.38.Tj

1. INTRODUCTION

Recent years the production of high quality concretes for various functional purposes is expanding in all industrialized countries. The properties of such concretes exceed the highest quality parameters regulated by the standards of different countries. These unique concretes can have a wide resource base of local raw materials, low cost, high durability, relative simplicity and accessibility of technology, low energy consumption and environmental safety. Production of concretes with specified functionality is achieved by modifying of its structure with various organic and mineral supplements. Many of them are specific, namely making influence on some characteristics of concretes; they practically do not change the other. Multicomponente of complex additives and the optimal mixing ratio of concrete mixture can effectively manage the processes of structure formation at all stages of technology of concrete preparation and can obtain the concrete with required technological properties and performance characteristics. These concretes are multicomponent, they lack the coarse aggregate. The share of mineral reaction-active filler in the concrete of 40 – 50 % by weight of cement maximizing the diluting effect of plasticizers. These concretes are fine-grained powder concretes, which significantly increases the isotropy of their properties. Currently the range of disperse fillers of high-strength concretes is greatly expanded. Scientific evidence shows that the use of such supplements is especially effective in combination with plasticizers and reinforcing elements. The fine-grained concrete or cement stone are usually reinforced by dispersion fiber. Dispersed reinforcement by fibers let to compensate the major disadvantages of concrete, namely low tensile strength and low flexural tensile, brittle fracture and to reduce shrinkage and creep [1, 2]. Such a fiber-concrete is highly resistant to corrosion except tensile strength increased in 2.5 – 3.0 times. This allows it to increase the durability of thin-walled structures operating under extreme conditions.

1.1 Reinforcing elements

Because of the extremely wide range of proposed fiber the question of choosing the most effective of them is still open. The fiber concrete with different fibers: steel, glass, polypropylene, carbon, etc is widely used in foreign practice [3, 4] but unfortunately the information on fiber-reinforced concrete, reinforced with hydro-silicate nanofibers is minor [5, 6]. Reinforcement of concrete by micro- and nanofibers is an effective means of increasing the compressive strength and tensile, fracture toughness and impact strength [7].

2. ACTUALITY OF THE TOPIC

A super heavy concrete with operational properties provided with high functional properties of the components themselves and their rational relation are used in the protective elements of nuclear reactors on fast neutrons. The technology of manufacturing of concrete components is complicated and they are very expensive. So far, super heavy concrete with density of 3600 – 4000 kg/m^3, strength = 20 MPa made of iron powder and serpentinite related heavy barium cement was used in blocks of biological protection of high power reactors. The disadvantage of this technology was the complexity of concrete and very high energy training its components. In addition, barium is a heavy element and production of barium cement will inevitably worsen the ecological situation in the cement plant. Small amounts of barium production of cement, compared with the volume of production of Portland cement, greatly increasing its cost. Transport costs for delivery of barite to the cement plant significantly effect on the value of barium cement.

It took the development of new efficient technologies of high-radiation-shielded of especially heavy concrete from local materials with improved technological and operational properties. In this paper we propose a replacement of the heavy barium cement by ordinary Portland cement, and the serpentinite by chrysotile (one of the three minerals of the serpentine group). Chrysotile is a natural nanofiber mineral with unique consumer properties. Nano fiber filler with high reinforcing properties obtained by defibrillation of marketable natural chrysotile, in combination with the plasticizer is proposed as a component of integrated high-strength modifiers nanoreinforcing concrete.

* smilikov@bsu.edu.ru

 © 2012 Sumy State University

3. PURPOSE OF THE REPORT

The purpose of this work is receipt of a multicomponent high-radiation-protective extra-heavy nanoreinforcing concrete modified by additives of different functionality with advanced technological and operational properties. The high bond strength of reinforcing elements with the cement matrix is necessary for obtaining of high-strength concrete [8].

Other forms of crystal hydrates like hydro-sulfo-aluminates, hydro-aluminates, hydro-ferrites of calcium, etc. are formed together with hydro-silicates and calcium hydroxide in the process of hydration of Portland cement clinker. The ratio between these crystal hydrates determines the properties of cement paste [9], and as a consequence, the adhesion strength of the reinforcement [10, 11]. A limiting value of concrete strength takes place for each type of aggregate. An excess of these value for the selected filler is economically disadvantageous because a slight increase in strength of concrete is accompanied by a significant increase in cement consumption. Typically, this limit occurs when the tensile strength of concrete close to the filler [12]. Rigid materials for high-dispersion-reinforced concrete should be clean, thoroughly washed, it should not contain dust, clay and humus must have a good grain structure and low voiding, not contain, if possible, weak grains.

Electron microscopy revealed that elementary chrysotile fibers are tubes with an outer diameter of ~ 30 nm, i.e. they are nanofibers. Aggregate connectivity of chrysotile fibers in the vein under tension in a direction perpendicular to the axis of the fibers is much smaller than the strength of the fibers to break. This feature of the asbestos is the basis of industrial technology of defibrillation commercial chrysotile.

Using of widespread natural fiber filler - chrysotile as a reinforcement material is largely limited to the relative complexity of fuzz commercial chrysotile [3] and to ensuring uniformity and homogeneity of distribution of fibers in terms of concrete mix. It is found that the longer fibrils with the same diameter, are more prone to clumping at all technological stages: loading, transporting, unloading, dosing, feeding into the mixer and stirring the mixture. Accordingly, as the length of the fibrils smaller as their tendency to form clots is less ceteris paribus. However, as the length of the fibrils (up to a certain size) is greater, as the force required for pulling out of the body of hardened concrete is greater too. The addition of fiber in the concrete mixture reduces its mobility and causes some difficulties in the preparation of a mixture of cement, water, aggregates and of fibrils. Increasing the length of fibrils leads to the fact that the concrete mix is becoming more connecting. An important problem arising in concrete reinforcing by fiber materials, is also a reduction in the workability of concrete mix to increase their content. It is usually necessary to slightly increase the amount of water in these mixtures and to increase the contents of fine particles like cement's and microfiller's. The concrete have high protective properties against thermal neutrons at the operation temperature if it containing no less than 1 mass % of chemically bound water. Now the serpentine is the most optimal in engineering-and-economical performance for super heavy concrete as a material with high (12 ÷ 14 mass %) content of high-temperature chemically bound water. The water in the serpentine concrete is very long preserved at temperatures up to 500 °C without any cooling.

Monofilaments obtained at full fuzz units of chrysotile can be used to obtain the highest quality of fine-grained composition of concrete with the flexural strength of 10 MPa, and compression strength of 110 MPa, using PTS500D0 cement. While the concrete of the same composition containing chrysotile fiber instead of the lizardite plate of the same chemical composition has a compressive strength of 20 MPa. These concretes mixtures referred are characterized by high workability.

The manufacturing of this concrete is possible using standard equipment of concrete plants. The production of the new ferro-magnetite-serpentine-cement (FMSC) concrete instead of ferro-barite-serpentinite- cement (FBSC) concrete has been organized by now. Investigation of FMSC concrete matrix with electron microscopy has showed that all components of concrete mixture in the matrix are distributed evenly. The electron microphotography (Fig. 1) shows a typical picture of magnetite grains (light) distribution in the cement matrix of concrete.

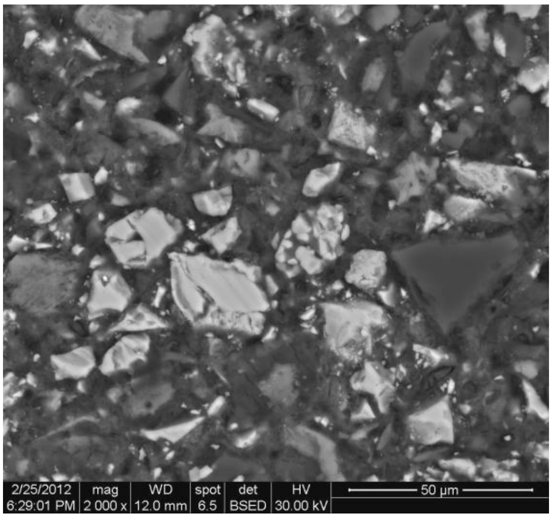

Fig. 1 – Distribution of magnetite in the matrix of FMSC concrete

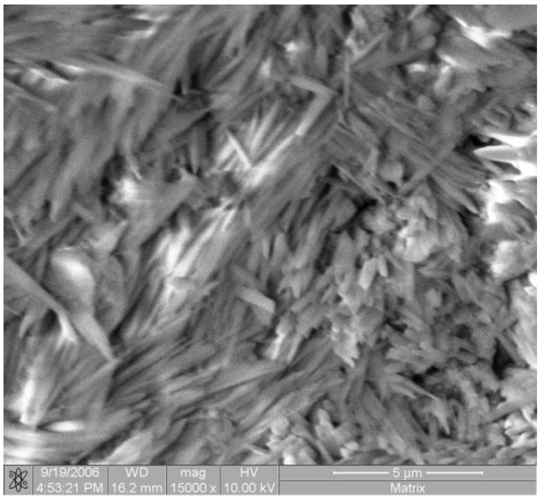

Fig. 2 – Morphology of crystals in the matrix of FMSC concrete

The investigation of crystals morphology on the spall of matrix of FMSC concrete with ion-electron microscope Quanta 200 3D by FEI company has shown that the matrix consists of fibers 3.5 μm long and 300 nm in diameter (Fig. 2). The comparison of radio-protective properties of earlier used FBSC material and new FMSC material has shown that thickness of the half-value layer for total γ-radiation for FMSC concrete is 6.2 cm which is a little smaller than for FBSC concrete (6.4 cm), but relaxation lengths of fast neutrons and neutrons dose rate in FMSC concrete are tangibly (> 10 %) smaller than in FBSC concrete.

4. CONCLUSION

The technological feature of the selected raw materials has been studied in accordance with the intended purpose. An optimal multicomponent mixture of concrete and the technology of preparation of high-quality heat-resistant super-heavy radiation shielding concrete nanoreinforced by chrysotile have been developed. The technical and economic performance indicators of such concretes significantly exceed similar concretes used in domestic practice.

REFERENCES

1. V.A. Antropov, V.A. Drobyshevsky, *Concrete and reinforced concrete* **3**, 3 (2002).
2. A.I. Zvezdov, *Concrete and reinforced concrete* **4**, 17 (2001).
3. F.N. Rabinovich *Concrete, disper-sion-reinforced by fibers* (Moscow Review VNIIESM: 1976).
4. M. Schmidt, *Schmidt Centrum Baustoffe und Materialprüfend*, **2**, 189 (2003).
5. V.V. Timashev, L.I. Sycheva, N.S. Nikonova *Selected Works. Synthesis and hydration of binders* (Moscow: Nauka: 1986).
6. A.A. Smolikov, *Concrete and reinforced concrete* **4**, 8 (2009).
7. A.A. Smolikov, V.M. Beresnev, A.I. Vesentsev *Proceedings 1-st International conference NAP-2011* **2**, Part 1, (Sumy: STU: 2011).
8. M.M. Kholmyanskii, *Contact of reinforce elements with concrete* (Moscow: Stroiizdat: 1981).
9. F.N. Rabinovich, *Dispersion reinforced concrete* (Moscow: Stroiizdat: 1989).
10. V.G. Batracov, *Modified concretes* (Moscow: Stroiizdat: 1998).
11. S.V. Kalashnikov, V.I. Kalashnikov, V.M. Zhuravlev, *Composite construction materials. Theory and Practice* (International scientific conference: Penza: 2005).
12. V.S. Demyanova, N.M. Duboshin, V.I. Kalashnikov, *Housing* **3**, 21 (1997).