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Fiber-reinforced concrete with mineral fibers and nanosilica

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Abstract

The article presents the research results of mineral fiber use as a reinforcing component for concrete. The introduction of nanosilica to fiber cement compositions improves the corrosion resistance of the mineral fiber, due to the fact that nanosilica binds $Ca(OH)_2$ during Portland cement hydration. Physical and mechanical properties of cement and fiber-reinforced concrete with the introduction of mineral fibers from basalt and slag waste materials and nanosilica are determined. A significant improvement of the properties of fiber-reinforced concrete is explained by the complex action of mineral fibers and nanosilica.

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Keywords: disperse fiber reinforcement, fiber-reinforced concrete, Portland cement, mineral fiber, nanosilica, temperature of hydration

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1. Introduction

The development of construction materials industry is associated with improvement of physical-mechanical and performance characteristics of concrete, concrete products and structures. It is known that the flexural strength of the concrete is much lower than compressive strength. The disperse reinforcement is used to solve this problem, which improves not only the growth of physical and mechanical properties, but is favorable to the improvement of deformation properties, crack resistance and concrete durability [1]. The use of mineral fibers is promising in producing fiber-reinforced concrete for a number of reasons; the examples of such mineral fibers are thin staple fiber and basalt roving, which are mainly produced by centrifugal-spinneret method and characterized by stable properties, uniformity of diameter and a low content of wastes.

Mineral fibers have been obtained with electrothermal method for melting raw material [2, 3]. The multi-step process is replaced by a one-step process for the electrothermal method in contrast to the cupola and bath methods, which allows reducing equipment costs and facilitates its operation. Melting is carried out on natural raw materials and industrial wastes in an electrothermal melting unit with further production of fibrous materials (basalt fiber and slag and ash fiber) and thermal insulation products based on them. The use of basalt rocks, deposits of which are found in Irkutsk region, Buryatia and the Trans-Baikal region, and slag waste for production of thermal insulation materials and products can not only expand the base of raw materials, but also utilize the ash and slag waste, which will reduce the environmental stress in the Baikal region. The experience with electro-melting units allowed to build a number of mini-factories in order to produce thermal insulating fibrous materials in the Republic of Buryatia and Zabaikalsky region. Mineral fibers are formed by the centrifugal blow method, which is the most common method for producing mineral fibers due to its high performance and relatively economic efficiency compared to others.

Mineral fibers can interact with Portland cement due their chemical resemblance. However, this factor might result in the destruction of mineral fibers and the reduction of reinforcing effect. The authors of the research [4] summarized different approaches to this problem and identified the main directions of the mineral fiber protection from the effects of cement alkaline medium:

- the use of cementless and cement low binders in fiber-reinforced concrete;
- modification of the mineral fiber surfaces;
- modification of the mineral fiber structure;
- the introduction of additives which reduce the alkalinity of the medium of fiber-reinforced concrete.

Each of the presented directions has its advantages and disadvantages; their use should be determined by the qualitative effect of improving characteristics of the final product and the technical and economic feasibility. Many studies were carried out in regard to the use of additives which reduce the alkalinity of the medium. They are mainly based on the use of silica-containing additives of various composition and origin [5, 6]. It should be noted that the mechanism of action of such additives for cement and mineral fiber is complex, and dosages of these additives varies over a wide range (5-20%). Silica-containing additives used for these purposes have generally a micro-level particle size. This particle size determines the mechanism and kinetics of cement hydration. The mechanism of action of nanoscale silica-containing additives towards the cement with fibers has not been studied extensively.

The objective of the research is to increase the corrosion resistance of the mineral fibers in the composition of hardening cement with nanosilica Tarkosil® T50 and to obtain a fiber-reinforced concrete with improved characteristics.

2. Materials and methods

The following raw materials were used for the current research in order to produce a fiber-reinforced concrete: plain Portland Cement (OPC) CEM I 32.5 N, mineral fibers on the basis of basalt and ash and slag waste, nanosized silica (NS) Tarkosil® T50.

Nanodisperse silica Tarkosil® T50 was produced by the apparatus, developed at the Khristianovich Institute of Theoretical and Applied Mechanics, Budker Institute of Nuclear Physics SB RAS and Bardakhanov LLC (Novosibirsk, Russia). Tarkosil® T50 has a specific surface Ssp = 50.6 m2/g (according to BET), so its primary particles have an average size of about 53 nm.