



RESEARCH OF CONCRETE COMPOSITES REINFORCED WITH BASALT FIBER

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ABSTRACT

Basalt fiber-reinforced concrete compositions were prepared based on 400-brand Portland cement of the Ohangaron cement plant, quartz sand and local produced basalt fibers of 5-15 mm long. As pozzolan additive local microsilica was used to bind portlandite, which was formed as a result of the hardening of the concrete composition and had a negative effect on the properties of the fiber. Comparing the mechanical strength of 7, 14 and 28 days of concrete samples with 5,10 and 15 mm long basalt fiber addition, a 3% basalt fiber (10 mm long) containing concrete composition was chosen as the optimal composition due to sharp and sustainable increase in the mechanical strength.

Introduction. In recent years' in Uzbekistan industry of production of construction materials has undergone sustainable development, with a focus on energy-saving, import-substituting, innovative, and new types of construction materials.

The Center for Economic Research and Reforms of Uzbekistan has analyzed the results of the development of the building materials industry over the past five years and reported that the industry has become modernized, technically and technologically equipped, energy-saving, economically stable, and competitive [1].

For instant, the use of basalt fiber in building materials become increasingly popular due to its durability, strength, and resistance to corrosion. Basalt fiber is a type of fiber made from basalt rock, which is found in abundance in Uzbekistan [2] and the company "Basalt Uzbekistan" became a leading producer of basalt materials in the Central Asian region [3]. The company offer a range of products, including basalt fiber, basalt rebar and mesh, which can be used in a variety of construction applications [4].

Nowadays there are many researches with fiber reinforced concrete made on the basis of different fibers. The production of concrete composite materials based on basalt fiber will help to solve the following urgent tasks:

- saves the main raw material base of production of building materials, i.e. resources and eliminates the shortage of natural raw minerals;

- local secondary resources could be used instead of imported raw materials;
- help to solve environmental issues, develop safe ecological system, to reduce land use, save energy sources and sharply reduce consumption costs.

Composite materials obtained on the basis of basalt fiber such as fiber-reinforced concrete composite allow to reduce the consumption of metal reinforcement elements. Due to the strong connection of basalt fibers with concrete, the tensile strength of concrete increases by 20...40%, its crack resistance and durability, and other properties significantly can be improved. Basalt fiber concretes have high crack resistance, bending strength, abrasion resistance. Products made of such concrete are not reinforced with grids and frames, so the technology of their preparation is more convenient and requires relatively little labor.

There are many scientific research works on fiber-reinforced concrete such as Williamson G.R, Aggarwal L.K, Graig R.J, Fernandez J.Ye, Muhammad Hisbany, Bin Muhammad Hashim, Naaman A.Ye, Borhan T.M, Brik V.M, Chen B, Liu J, and Martti Kiisa [5-7].

Basalt fiber is considered to be an eco-friendly alternative to traditional building materials. Optimizing the composition and production of building materials containing basalt fiber, can help to reduce the environmental impact of construction practices in the region of Central Asia [8-9]. Especially important the understanding of the environmental footprint of materials used in modern building materials design. The use of basalt fibers in building materials compared to other types of fibers (metal, carbon, glass fibers) is environmentally friendly, sustainable and economically justified. Use of inert and thermal stable basalt fibers in the concrete composition does not lead to chemical interactions, not accompanied by the release of hazardous substances into the environment.

Methods and Materials. For preparation of fiber-reinforced concrete samples, PS400D20 brand of "Ohangaron cement" plant was used as a binder, construction sand with a particle size of no more than 2.5 mm - as dispersive additive. Fiber obtained from the basalt rock of Osmansay Deposit (Jizzah region) was used. The chemical composition of basalt fiber is as follows: SiO_2 - 42.49; Al_2O_3 - 11.35; CaO - 20.10; MgO - 6.77; $\text{Fe}_2\text{O}_3 + \text{FeO}$ - 11.28; $(\text{K}_2\text{O} + \text{Na}_2\text{O})$ - 8.01 wt.%. Characteristics of the fiber: diameter 10 μm , length - from 110 to 120 mm; operating range: from -200 to +600 °C; elastic modulus - 5600-7800 kg/mm². Jizzakh basalt fibers were added to the mass by more than 100% as reinforcing elements; the composition of 3 types of composites was calculated: samples containing 5 mm, 10 mm, 15 mm basalt fiber. Pozzolan additives (local microsilica) in the amount of 1-3% were used to bind the portlandite formed as a result of the hardening of the concrete composition to decrease its negative effect on the properties of the fiber. Mechanical property of concrete samples was investigated on 7, 14, 28-day of standard curing, structure of materials was studied SEM-electron microscopy and XRD- methods of analysis. To interpret XRD-patterns, the Match program package (Crystal Impact GbR, Bonn, Germany) was used.

Results and discussions. All components of the concrete mixture are dosed by weight. According to GOST 17608-2017 [10], a concrete mixture was prepared with water content (by weight of cement): 30 - 40%. It will be necessary to take into account the moisture content of the raw materials. In the process of production of products, it is possible to slightly correct the components of 1.5 ... 3.0% by weight of cement. The basalt fiber-concrete mixture is prepared in a concrete mixer. The concrete mixture is cooled with warm water at a temperature of 30 - 32 °C.

For the study of flexural and compressive forces, samples of 40x40x160 mm size that meet the requirements of GOST 10180-2012 [11] are prepared and cured under normal conditions. Three samples of each composition (with basalt fibers of 5 mm, 10 mm, 15 mm long) were studied for mechanical measurements at 7, 14 and 28 days.

Mechanical strength on compression of concrete samples with addition of 5 mm long basalt fiber on 7, 14 and 28-day showed that, compared to concrete samples without fiber, the mechanical strength increases in basalt fiber composite material. It was found that the samples with 5 mm long basalt fiber addition in the amount of **2%** have the highest mechanical properties (38.3 MPa). Analogically samples at 28 days of standard curing with 10 mm basalt fiber have shown the highest mechanical parameters with the addition of **3% fibers** (39.3 MPa) and samples with 15 mm basalt fiber have shown the highest mechanical strength on compression with **2 % of addition** of fiber (38.4 MPa).

As a result of the comparison, the optimal composition and length of basalt fibers were determined. As a result of the addition of **10 mm long basalt fibers**, rapid hardening of concrete and a rapid increase in mechanical strength are observed. **A 3% addition of basalt fiber to concrete composition** (10 mm long) was chosen as the optimal composition - a sharp increase in the mechanical strength of the 14-day sample is observed in the sample compared to other compositions.

Based on XRD-analysis the main crystal phases in basalt fiber reinforced concrete were identified as calcium silicate-hydrate – Rosenhahnite $\text{Ca}_2\text{Si}_3\text{O}_8(\text{OH})_2$ (Ref. # 00-00-083-1242 in Match!), silicon oxide SiO_2 (Ref. # 00-086-1630) and calcium-iron silicate Hedenbergite $\text{CaFeSi}_2\text{O}_6$ (Ref. # 00-071-1502). A large amount of calcium hydroxide that formed during the hardening process of Portland cement can break down basalt fibers and have a negative effect on concrete compositions. Addition of pozzolanic microsilica to the composition helps to bind calcium hydroxide: microsilica reacts with calcium hydroxide to form a new crystalline phase - calcium silicate-hydrate rosenhahnite, which leads to a rapid increase in the mechanical strength of the studied samples [12].

Conclusions. A basalt fiber-reinforced concrete samples containing Ohangaron Portland cement, construction sand and 3 % of Jizzakh basalt fibers of 10 mm long, as pozzolan additives local microsilica shows a sharp increase in the mechanical strength in early stage and optimal results on 28-day of standard curing. XRD analysis showed that main hydration products include calcium silicate-hydrate (C-S-H), silicon oxide and calcium-iron silicate (C-I-S). Both products - C-S-H and C-I-S make major contributions to improvement of the mechanical properties of cements. Addition of basalt fibers helps to obtain denser concrete structure with no voids and cracks, this ensures high mechanical performance of the obtained samples, allows to get quick-hardening and high-strength concrete. Basalt fiber reinforced concrete can be used in various fields of modern construction works, it is considered economically and ecologically effective when it is necessary to increase the physical-mechanical properties of products, with a relatively low increase in price.

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