Study of the properties of polymer composites – reinforcement based on glass and basalt fibers

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Composite fittings are increasingly used in various industries and the economy. The use of such compositions in construction requires a modern engineer to have in-depth knowledge of the choice of materials. In this regard, a comparative analysis of composite reinforcement based on glass and basalt fibers was conducted. Price monitoring of composite fittings from leading local manufacturers was conducted. The main deformation-resistance properties of basalt-plastic and fiberglass reinforcement are determined based on the results of numerous tensile tests of rods. A more efficient and economical design of the anchor sleeve is given in comparison with the recommendations. By many criteria, it was concluded that basalt-reinforced plastic reinforcement was slightly superior to fiberglass.

Keywords: Composite Reinforcement, Fiber, Fiberglass, Basalt Plastic, Strength.

Introduction

Recently, we can observe an increasing use of environmentally friendly, natural fibers as a reinforcement for the production of lightweight, inexpensive polymer composites on a global scale. One such interesting material that is now widely used is basalt fiber, which is economical and offers excellent properties over glass fibers. The main advantages of these composites include high specific mechanical-physicochemical properties, biological decomposition, and non-abrasive properties to name a few. This article provides a brief overview of basalt fibers used as reinforcing material for composites and discusses them as an alternative to the use of glass fibers. The article also discusses the basics of basalt chemistry and its classification. Research publications in the field of basalt fibers and attempts to show increasing trend inactivity are also covered. The following sections discuss the improvement of the mechanical, thermal, and chemical resistance properties achieved for application in specific industries. Since its discovery by American scientists in 1923, basalt has been the classified material of choice for military research and was widely used in defense and aeronautics by the United States (US), Europe, and the Soviet Union during World War II.

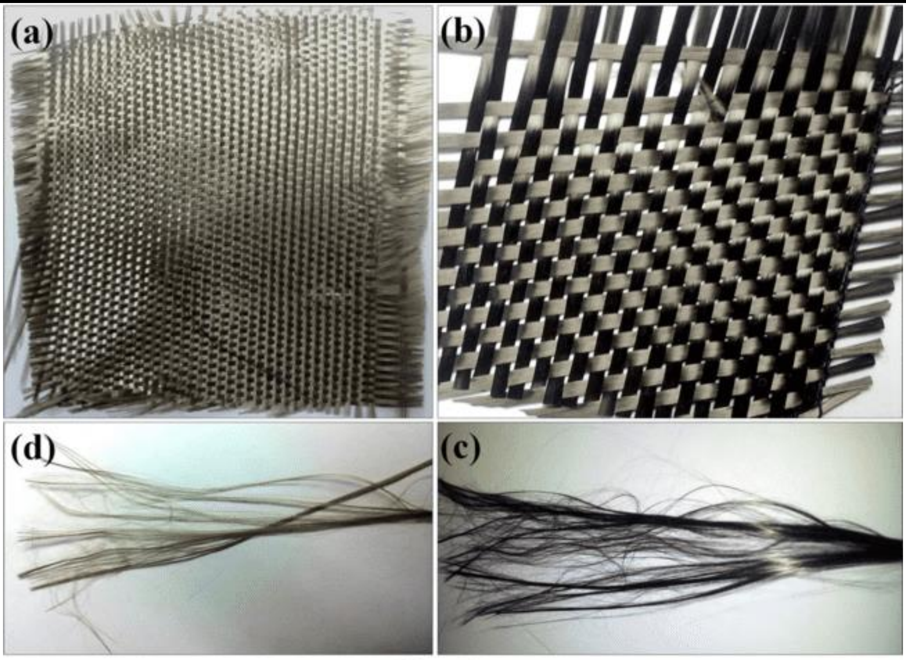

Fig. 1

Fig.1 shows the widely used basalt fibers and carbon woven fabrics. In recent decades, the growing interest in the use of basalt fibers due to improved mechanical properties has taken the polymer industry by storm. These fibers are now used in the production of lightweight, high-quality hybrid composite materials for infrastructure and civil applications. In general, hybrid nanocomposites are produced when two or more combined foreign materials are incorporated or reinforced into a common host matrix. A synergistic effect is achieved by mixing two or more materials, which provides new and superior properties in the material, such as improved elastic modulus, flexibility, lightweight, and flame retardant ability. These qualities are already present in carbon fiber (CF) and are useful in many major engineering applications such as aircraft (civil and defense), automobiles, shipbuilding, sports equipment, and construction. However, CF-based composites are flexible to stress concentrations due to the brittleness of the carbon fiber. The main drawback in the carbon composite industry is production costs, resulting in very low loads. In the composite (carbon-fiber-reinforced plastic-CFRP) the problems of weakness and brittleness can be solved by the method of hybridization, i.e. by replacing the layers of carbon fibers with flexible fibers. This can lead to cost benefits and improved physical and mechanical properties. Using this technique, it is possible to synthesize and produce new types of materials. For example, Park and Zhang introduced polyethylene (PE) fibers along with carbon fibers in an epoxy matrix to produce a hybrid laminated composite material. During the experiment, they chose PE fiber because of its high elongation at break and its high specific strength and stiffness. Based on their observations, it was concluded that the high mechanical properties of the hybrid-based composition are strongly related to the state of the reinforcing fiber. Thus, whenever CF was placed in the peripheral (outermost) layer, the composition provided a high degree of flexibility. Based on the above observations, strong, lightweight, durable, and cost-effective fibers are now required to produce hybrid composites. There are several organic and inorganic fibers on the market today, but most of them do not have structural strength or durability or are too expensive to use at moderate loads. Basalt fiber is currently the selected material and is an inorganic fiber with very good modulus, high strength, improved deformation, high-temperature resistance, excellent stability, good chemical resistance, it is easy to process, non-toxic, natural, environmentally friendly, and inexpensive. Basalt fiber is obtained after extrusion from molten igneous volcanic rock based on basalt located in flowing lava. The extrusion process of basalt fiber is much more economical and simpler than any competing fiber. Fiber sizes are typically 10 μm to 20 μm. Several of these properties (e.g., the tensile and compressive properties of basalt) are better than E-glass fibers and much cheaper than their carbon counterparts. Thus, basalt fibers are increasingly being used as a new type of reinforcing material for the production of hybrid composites/laminates. Based on the advantages of basalt fiber, there are potential applications in the production of basalt-epoxy composites, which are lightweight and have strong load-bearing properties that are useful in the heavy automotive industry. Currently, CF composites are widely used in the automotive industry due to their high mechanical properties. Using This reinforcing material can reduce the car’s body weight by 40-60%, but its cost makes the whole process not currently economically viable. Thus, the need to reduce the cost of production and delivery without compromising the mechanical properties of CFRP-based composites is important. As mentioned above, the promising nature, low cost, and effective properties of basalt fibers can make basalt a promising candidate for strengthening CFRP-based compositions. There are several reports of the incorporation of various reinforcing basalt fibers within composite laminates. Lopresto et al. studied and compared the compressive strength, Young modulus, and ductility of basalt fiber-reinforced plastics or polymers (BFRP) with fiberglass plastics (GFRP) and determined that basalt is superior and has potential. A similar report was prepared by Manikandan et al. On the other hand, the mechanical, physical, and physicochemical properties of fiber-reinforced plastic or polymer have been further improved through the introduction of foreign fillers such as nanoparticles, and fiber fillers. surface changes of fibers. To date, very few researchers have performed surface treatment to improve the properties of basalt fibers. As mentioned above, another possible alternative to improving the properties of basalt is to hybridize it with carbon fibers. This makes it very lightweight, durable, and economical and opens up many possibilities in the hybrid composite world. High bending modulus and high interlaminar shear strength were reported for basalt woven fiber reinforced composites (BWFRC). They also found that the BWFRC produced had similar electrical properties to electronic glass composites. As for the structural properties of basalt fiber, several reports are showing the promising potential of the existing material. Previously, basalt was the preferred material (as fiber) in the construction industry, and since then it has been widely used as an external or internal reinforcement within concrete materials. It can also be used in other applications such as basalt sea, impact, or ballistic resistance applications. Islam-Farsi and others. He produced a composition by crushing basalt fiber and mixing it into a polypropylene-clay mixture. This approach dramatically increased not only the flow strength but also the elastic modulus of the composite. Because basalt is more useful and flexible, basalt can be incorporated into the matrix as a reinforcement in a variety of forms other than fibers. Shapes such as rods, bars, and textiles are possible. This review focuses on the widespread use of basalt fibers in the synthesis and production of lightweight compositions with highly improved mechanical properties as a stable, inert, environmentally friendly, and non-reactive reinforcing material. This review also highlights the use of compositions prepared using a polymer matrix reinforced with basalt fiber. It is currently saturated with products of various types and purposes. A non-standard approach to solving the tasks set in conjunction with the use of innovative products and technologies in the production of building structures allows getting rid of often ineffective conservatism in the construction industry. The result of technological development in collaboration with industry and the scientific community is composite fittings. Although the creation and research of this type of non-metallic fittings began in the 60s of the last century, composite fittings are new material and large-scale production and introduction have only just begun occurs [1].

Composite reinforcement is a building material consisting of fibrous yarns bonded with a polymer binder [2]. Thermosetting synthetic resins typically act as a binder, the choice of which depends on the reinforcement requirements. Thus, the use of polyester resins allows to minimize the electrical conductivity and the use of epoxy phenolic resins allows to increase the level of resistance to aggressive environments. Glass, basalt, aramid, and carbon roving can be used as fiber material, which defines the name of the manufactured reinforcement. There is also a hybrid option, for example, rod fiberglass and its periodic wrapping of basalt, and so on.

In most cases, the profile of the composite reinforcing bars has a periodic corrugation. Due to its low adhesion to concrete, the use of rods with a round smooth surface is not recommended for working reinforcement. For better adhesion to concrete, they are additionally sprinkled with fine or powdered sand during the manufacturing process.

Composite reinforcement works as an analog of metal reinforcement, which allows for expanding the scope of concrete structures. Therefore, depending on the type of fiber used in production, a qualitative analysis of its properties becomes relevant. Glass fiber (FRP) and basalt-plastic (ABP) composite reinforcement types are the most widely used in construction practice, as a result of which they will be discussed later.

Basalt fiber – is produced from basalt rocks by melting them and converting the melt into fibers.

Basalts are rocks of igneous origin, natural raw materials. The main energy consumption for the preparation of basalt raw materials for the production of fibers is the enrichment and initial melting of basalt raw materials, which were formed under natural conditions, which, however, does not guarantee its safety and lack of carcinogenicity.

We produce and use basalt continuous fibers, short-staple fibers, and super-fine fibers.

Purpose of basalt fibers: continuous fibers – production of reinforcing and composite materials and products, fabrics, and non-woven materials; staple short fibers - production of heat-insulating materials, mats, and plates; superfine fibers - production of heat and sound insulating materials of high quality (canvases, mats, boards, cardboard), materials for filters.

Production

The production of basalt fibers is based on the selection of basalt rocks suitable for the production of fibers (“long” basalts) [3], the melting of basalt raw materials, and the production of fibers from the melt through spunbond feeders, or fiber formation devices [4].

The use of basalt raw materials, the initial melting and preparation of which is carried out in natural conditions, makes it possible to produce basalt fibers with low energy consumption.

The production of basalt continuous fiber (BCF) is carried out on modular and feeder furnaces and installations [5]. The drawing of basalt continuous fibers from the melt is carried out through platinum-rhodium spinneret feeders by winding spindle machines. Further processing of BCF into reinforcing, composite materials, fabrics, and non-woven materials is carried out using "cold technologies" with low energy consumption.

At present, industrial technologies and equipment for the production of BCF have been developed, and BCF plants and the production of BCF materials have been created [6].

The production of super-thin fibers is carried out according to a two-stage technology - melting basalts, drawing primary fibers from the melt, and blowing primary fibers into super-thin ones with a high-temperature jet of hot gases from the blowing chamber.

The production of staple thin fibers is carried out by melting basalt rocks in melting furnaces of a bath or cupola type, feeding the melt to fiber formation devices - rolls, or blowing heads.

BCF production technology is one-stage: melting, basalt homogenization, and fiber extraction. Basalt is heated only once, which makes it possible to obtain the required product - BCF. Further processing of BCF into materials is carried out using "cold technologies" with low energy consumption.

Types and properties

Basalt continuous fibers (BCF). Basalt continuous fibers are produced with diameters of 8 – 11 microns (mk), 12 – 14 microns, 16 – 20 microns, and the length of the fibers is 25 - 50 kilometers or more.

Staple short fibers. The diameters of elementary fibers are 6 – 12 microns, the length is 5 – 12 mm.

Basalt super thin fibers (BSTV). Diameters of elementary 0.5 – 3 microns, length 10 - 50 mm.

Basalt fibers are produced from igneous basalt rocks. This determines the high chemical resistance of the fibers to the effects of alkalis, acids, and chemically active media; the possibility of long-term operation of fibers under the influence of the environment, moisture, and seawater; incombustibility, and high thermal resistance of fibers.

In the process of drawing, continuous fibers from basalt melt acquire sufficiently high strength characteristics. The tensile strength of basalt continuous fibers ranges from 2800 to 4800 MPa.

Basalt staple short and, especially, super-thin fibers have good thermal and sound insulation characteristics. The temperature range of long-term use of basalt fibers is from -200 to +6000C. Basalt fibers from acidic basalt rocks have higher application temperatures up to + 750,…. + 8000C.

The combination of properties and characteristics of basalt fibers provides the possibility of producing a whole range of materials and their wide application in the construction industry, road construction, industry, and energy.

Features and Benefits

Basalt fibers are highly resistant to chemically active media (acids, alkalis, salt solutions), high temperatures, and open flames. The resistance of basalt fibers to water and seawater is 100%, to alkali 96%, and acid 94% [3]. The chemical resistance of basalt fibers allows them to be used for reinforcing concrete and asphalt concrete, for the production of pipes, tanks for the chemical and petrochemical industries, composites for hydraulic engineering, and coastal and offshore construction.

The temperature range of long-term use of basalt fibers is from – 2000C to + 6000C. Basalt fibers are non-combustible and fire-resistant, in case of fire they withstand the effects of flame and temperatures of +900, ... +10000C. Heat-insulating and fire-resistant materials based on staple and superfine fibers withstand standard fire and do not emit smoke when heated and exposed to flame. The hygroscopicity of basalt fibers is 6 times lower than that of glass fibers. Only heat and sound insulating materials based on super-thin basalt fibers are used in the aviation and shipbuilding industries, as they do not accumulate excess moisture, do not burn, do not smoke in a fire, are high-temperature, and fire-resistant.

Basalt fibers are dielectric, transparent to electromagnetic radiation, radio rays, and magnetic fields, they are the basis for the production of electrical insulating materials, as well as radar and antenna radomes.

These characteristics determine the advantages of basalt fibers in comparison with mineral, glass, carbon, and chemical fibers in terms of the durability of operation under the influence of the environment, seawater, and chemically active media.

Basalt continuous fibers (BCF) have sufficiently high strength characteristics and elastic modulus, as well as a potentially low production cost (because basalt is a finished raw material, the main energy costs for the preparation of which are made in natural conditions).

Characteristics of BCF are 65 – 70% determined by the initial basalt raw materials and, accordingly, by 35 – 30% by production technologies, the operation of process equipment, and the lubricants used (coatings on the surface of the fibers).

BCF is a relatively new type of fiber, the first industrial production of which was created in the Ukrainian SSR in 1985. To improve the strength characteristics of BCF and reduce the cost of their production, work is being carried out on the targeted selection of basalt rocks most suitable for the production of fibers [7], the improvement of technologies and equipment for the production of BCF. To date, four generations of process equipment produced by BCF have been created [8]. The work carried out made it possible to achieve certain characteristics and indicators of BCF, to significantly reduce the cost of production. The table shows the characteristics of BCF in comparison with glass fiber and carbon fibers.

	BCF	E-glass	S-glass o	The carbon fiber
Breaking strength, M Pa	3000~4840	3100~3800	4020~4650	3500~6000
Modulus of elasticity, G Pa	79.3~93.0	72.5~75.5	83~86	250~450
Elongation at break, %	1.5 – 2.1	4.7	5.3	1.5~2.0
Primary fiber diameter, micron	6 – 21	6 - 21	6 – 21	5 – 15
(weight in grams of roving)	60 - 4200	40 - 4200	40 - 4200	60 – 2400
Temperature of application, °C	-260 +600	-50 +350	-50 +300	-50 +400
* The cost of prom. production USD/kg	0.9 – 1.2	1.1 – 1.5	2.5 – 3.0	15 – 25
Sales cost, USD/kg	2.6 – 3,0	1,5 – 2.0	3,5	25 – 50

*The cost of industrial production of BCF is determined by the low cost of basalt raw materials and the use of energy-saving technological equipment of the third and fourth generations.

The strength characteristics of BCF exceed those of E-glass fiber, are close to special and carbon fibers, and at the same time have a low production cost. In terms of its strength characteristics, BCF occupies an intermediate position between glass fiber and carbon fibers. Taking into account the whole complex of characteristics, BCF has a number of advantages compared to glass, carbon, and chemical fibers, as well as a better performance/cost ratio.

Basalt fibers created from rocks of igneous origin, in contrast to artificial glass, carbon, and mineral fibers, are the only fibers that are produced from natural raw materials of igneous origin.

Theoretical foundations of BCF production, accumulated experience, laboratory equipment, BCF pilot equipment, and methods for conducting research on basalt deposits make it possible to assess the degree of their suitability for the industrial production of BCF and to determine the technological parameters of melting and melt characteristics, to obtain primary continuous fibers and evaluate their performance.

The characteristics of BCF are of great interest in the market for reinforcing and composite materials.

Main advantages.

• Basalt fibers have increased natural resistance to environmental and aggressive environments, flames and high temperatures, and resistance to vibrations. The fibers are resistant to mold and other microorganisms. This determines the durability of the use of basalt fibers and materials based on them in the construction industry, the automotive and aviation industries, shipbuilding, and energy.

• Good electrical and thermal insulation characteristics, long service life. This property allows the use of basalt fibers for the production of heat-resistant materials, as well as a fire-retardant and fire-fighting material.

• Increased chemical resistance in acidic and alkaline environments, in seawater compared to E-glass. This property of basalt fibers opens up broad prospects for their application for structures exposed to moisture, salt solutions, and chemical and alkaline media. Allows consumers to replace metal structures and parts that are subject to corrosion under the influence of chemically active environments with light, strong, and corrosion-resistant materials made of basalt fiber. BCF can be used for reinforcing concrete, in the construction of offshore structures. On-road surfaces, chopped basalt fiber increases the strength of concrete and asphalt concrete, protects concrete and reinforcement from the penetration of anti-icing salts and aggressive substances, and increases residual strength and resistance to freezing and thawing.

The chemical resistance of basalt fiber is one of the defining competitive advantages for the production of filters for the chemical and metallurgical industries, for the production of containers and pipes for the chemical industry and utilities.

• Ecological purity of the material. Full compliance with the REACH program. The finished product does not contain harmful substances and fully complies with the REACH protocol and all hygiene standards.

• High durability. The service life of materials is 50 years. The use of such materials makes it possible to achieve savings due to durability and enhances the safety of industrial facilities.

• Low price compared to the cost of special fiberglass [9].

Application

Basalt fibers are widely used for heat and sound insulation, fire-resistant materials and fire protection systems, filters, production of technical fabrics and non-woven materials, reinforcing, composite materials, and products. Basalt staple short fibers are used for the production of heat-insulating mats and plates, material for filters of gaseous emissions with elevated temperature, and chemical active liquid media, for hydroponics in agriculture.

The use of basalt super-thin fibers (BSTV): production of heat and sound insulating materials of high quality - canvases, mats, plates, cardboard for shipbuilding and aviation; materials for fine filters; fire-resistant and fire – fighting materials and systems for critical facilities of nuclear power plants, oil refineries, gas pumping stations, public, and high-rise buildings.

Basalt continuous fibers (BCF) are used for the production of a wide range of materials and products: reinforcing materials - chopped fibers for dispersed volumetric reinforcement of concrete and asphalt concrete, composite reinforcement, reinforcing meshes, building and road meshes, and reinforcing tapes [10], technical fabrics of various weaves and density, non-woven materials - basalt paper, canvases, chopped fibers, and needle-punched canvases. Composite materials and products – profiles, pipes of medium and large diameters, tanks, tanks, high – pressure cylinders, bridge supports and ceilings, products for mechanical engineering, parts for automobiles, ships, and aircraft. Electrical insulating materials and products – load –

bearing cores of power transmission line wires and fiber optic cables, electrically insulating and protective sheaths of power cables, supports, traverses, and insulators of power transmission lines, materials, and products for transformer substations.

Areas of application of basalt fibers: construction industry, earthquake – resistant, hydraulic and coastal construction, road construction of automobile and high – speed railway lines, utilities, mechanical engineering, automotive, aviation and shipbuilding industries, energy, agriculture.

In industry

The German engineering bureau EDAG has developed a concept car, which is used in the production of basalt fiber. As reported, "the material is distinguished by lightness, strength and environmental friendliness, moreover, in production, it will cost less than aluminum or carbon fiber"[11].

Reinforcement of reinforced concrete structures with basalt fiber will cost less than carbon fiber, the first tests were carried out by the INTER / TEK Research Institute of Armed Forces in Yekaterinburg based on the Ural NIAS Institute.

Materials based on basalt fiber have the following important properties: porosity, temperature resistance, vapor permeability, and chemical resistance.

• The porosity of basalt fiber can be 70% by volume or more. If the pores of the material are filled with air, then with such porosity it is characterized by low thermal conductivity.

• Temperature resistance is a very important property of thermal insulation materials, especially when used to insulate industrial equipment operating at high temperatures. The temperature resistance of materials is characterized by the technical temperature of use, at which the material can be operated without changing the technical properties.

• Vapor permeability is the ability of a material to pass water vapor through its pores. If there are communicating pores in basalt fiber materials, they pass the same amount of steam as air. Due to their high vapor permeability, these materials are almost always dry during operation; vapor condensation occurs mainly in the next layer, on the colder side of the barriers.

• Chemical resistance. Basalt fibers have good resistance to organic substances (oil, solvents, etc.), as well as to alkalis and acids.

Due to these properties, basalt fiber and materials based on it are increasingly being used today for such purposes as:

• heat and sound insulation and fire protection in residential and industrial buildings and structures, baths, saunas, cabins, etc.;

• thermal insulation of power units, large diameter pipelines;

• thermal insulation of domestic gas and electric stoves, ovens, etc.

• insulation of reconstructed buildings with installation both inside and outside;

• insulation of flat roofs;

• isolation of oxygen columns;

• insulation of low-temperature equipment in the production and use of nitrogen;

• in industrial refrigerators and refrigerating chambers, household refrigerators;

• in three-layer building sandwich panels;

In construction

SMU 19 of Mosmetrostroy used sprayed concrete reinforced with basalt fiber as a tunnel lining.

The research and production company “Basalt fiber & composite materials technology development co., LTD” (“BF&CM TD”), is engaged in the development and development of technologies, the manufacture of process equipment, and the organization of industrial production of basalt continuous fibers (BCF), has completed the design and reconstruction of heating furnaces and thermal equipment using the results of this work.

Methodology

Most of the indicators of composite fittings (resistance to corrosion and high temperatures, thermal and electrical conductivity, etc.) were obtained by analyzing the collected scientific material on this topic. The price of a linear meter of composite fittings was adopted based on monitoring the prices of leading domestic manufacturers of these products. Determination of deformation-resistance properties of reinforcement barriers was carried out using continuous testing. WEW-600D machine and YYU-10/50 extensometer.

Main Part

The basic principles of using composite reinforcement in concrete structures are similar to the principles of designing reinforced concrete elements [12]. Therefore, in the comparative analysis of glass fibers, basalt-plastic reinforcement has properties that allow it to act as an alternative to metal reinforcement or to work with it.

One of the main criteria for choosing the type of composite fittings is the price paid per linear meter of the final product. Price monitoring for composite fittings showed that the cost of ABP fittings is 50-60% higher than that of ASP fittings. It depends on the cost of raw materials (fibers) because the technological processes in the production of materials are very similar.

The main disadvantages of fiberglass and basalt-plastic fittings are low heat resistance (compared to metal). The fibers underlying these composite materials are highly heat resistant, but the bonding plastic component is not resistant to high-temperature effects. The fire resistance of ABP is about 300 ° C, ASP – 150 ° C. This means that concrete structures reinforced with such rods have low fire resistance.

The electrical conductivity of an ASP armature is not observed, so it can be considered a dielectric. In classical production, ABP fittings are also dielectric, but they can be given a wide range of adjustable electrical conductivity properties if required.

The main advantages of basalt over glass fibers are low (order of magnitude less than glass) water absorption and very slow processes of fiber corrosion under the influence of aggressive environments. The mechanism of fiberglass degradation is complex, the main destructive factor is the migration of active chemicals in the surface layer and through cracks on the surface of fiberglass, i.e. the ability to absorb water and aqueous solutions. The process is accelerated sharply by cyclic wetting – drying and freezing-thawing cycles. Packing the fiberglass in a polymer matrix significantly slows down the process, but does not stop it.

Basalt roving consists mainly of aluminum and silicon oxides, which are badly moistened with water; the glass contains large amounts of oxides and salts of alkali metals, which in turn are well moistened and also soluble in water. Basalts with different chemical compositions are less sensitive to typical types of glass corrosion: leaching of the silicate network (ion exchange) and hydrolytic melting. Based on this, ABP reinforced concrete structures can be considered corrosion-resistant and durable.

Due to the low thermal conductivity of glass-plastic (0.45 W / m^2) and basalt-plastic (0.55 W / m^2) fittings, their use as a connection for multilayer structures has become traditional [13]. This feature allows you to exclude "cold bridges". Both types of fixtures under consideration are radio transparent and non-magnetic.

A series of stress tests were performed on rods with a nominal diameter of 6 mm to determine the main deformation-strength properties of the ASP and ABP types of reinforcement.

Control of the stress-strain state of the armature was carried out in Automatic mode using a specially equipped computer (Fig. 2), which takes the value of the tensile strength from the press and the value of absolute deformations from the extensometer.

An important issue when testing a composite armature for tension is the method of fastening it to the handles of the tension machine. To prevent the armature in the handles from slipping and falling, the authors improved the design of the anchor sleeve (Fig. 3). For an anchor given by an increase in the nominal diameter of the rod, a larger length or length and diameter of the pipe must be obtained. Polyester resin NOVOL Plus 720 was used as a frost-resistant compound.

It should be noted that the rods are manufactured by ROCK BAR Galen, so the results obtained (Table 1) may differ slightly from the fitting-like tests of other manufacturers.

The strengths and average modulus of tension of the ABP-type armature are 7.6% and 6.3% higher than those of the ASP, respectively, and the relative elongation is almost the same

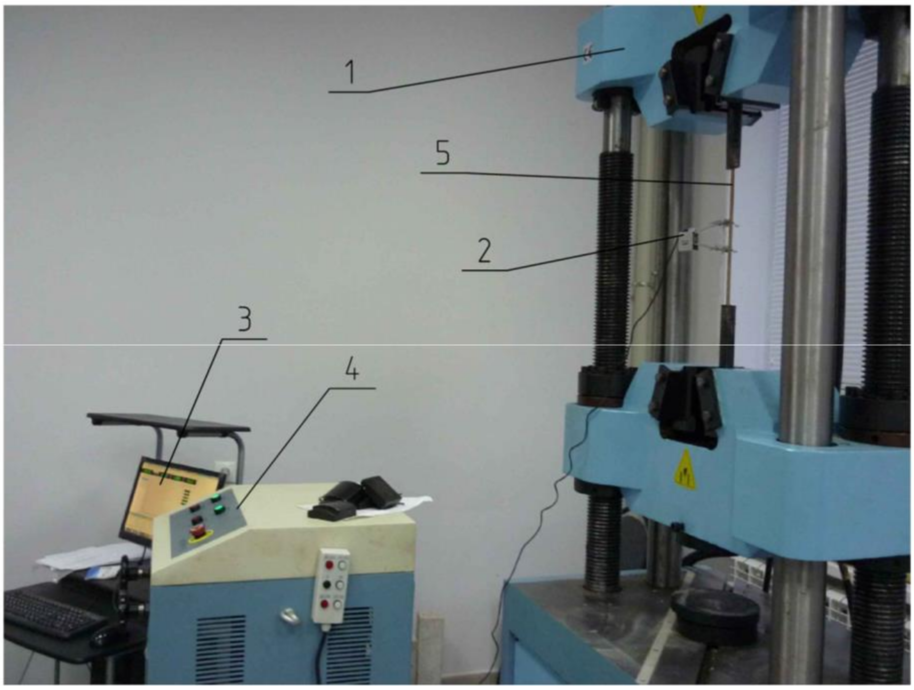

Fig. 2. Composite reinforcing tension testing equipment: 1 – hydraulic press WEW-600D; 2 – extensometer YYU-10/50; 3 – computer reading; 4 – click on the control panel; 5 – armature

a b

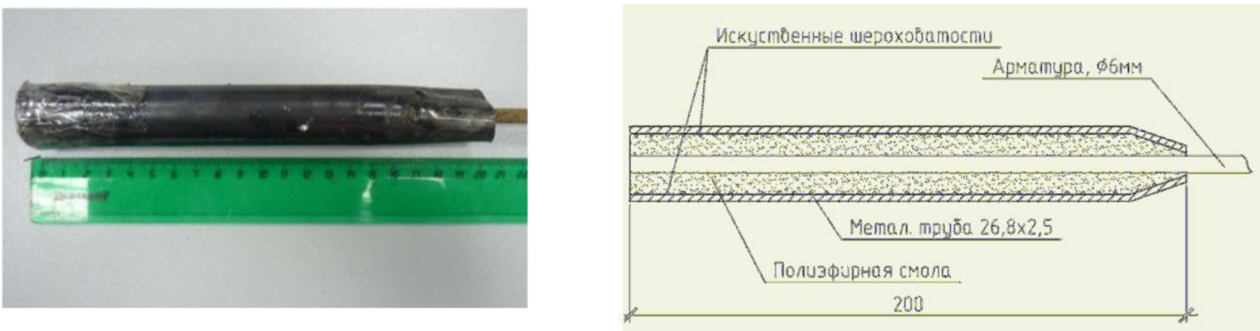

Figure. 3. Design of anchor sleeve for elongation test of composite reinforcement: a – appearance; b – device diagram

Table 1
Average values of strength properties of composite reinforcement

Reinforcement type	Intension void, MPa	Deformation module at voltage, MPa	Relative elongation, %
fiberglass reinforcement rock bar, d=6 mm	1166.4	48306	2.41
Basalt armature rock bar,d=6 mm	1254.6	51359	2.43

The distribution of power values in the described test is up to 7% for ASP and up to 25% for ABP. This allows us to say that it is better to control the quality of production of fiberglass fittings, so lower reliability factors can be used in determining the design features for this type of fittings.

The destruction of all rods is brittle, tearing along the fibers, and their longitudinal delamination at the workplace (Fig. 3) is not at all characteristic of the nature of the destruction of metal fittings.

For both types of reinforcement adopted, the relationship of “stress-deformation” to the gap has a proportional (linear) shape.

Conclusions

The main advantage of ABP fittings over ASP fittings is their high corrosion resistance. By many other criteria, the evaluation of basalt-plastic reinforcement is irrelevant. glass exceeds fiberglass, as well as on the main indicator - it is much lower in terms of price. Therefore, from an economic point of view, fiberglass alternative (metal) reinforcement is more efficient.

Fig. 4. Disposal of composite fittings

At this stage of the work, the authors prefer ASP-type composite reinforcement, for which joint work with heavy concrete and metal reinforcement is studied.

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