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A study of basalt-composite reinforcement of Georgian production and standard preparation

Tamaz Khmelidze[1], Vladimir Kikadze[2], Marlena Rajczyk[3]

ABSTRACT:
Analyzing the development of the modern construction industry clearly shows the steady increase in the share of load-bearing and enclosing structures made based on building materials obtained by new technology. Polymer-based composites have a special place in this range of materials. The use of composite materials in construction can solve such important issues as reducing operating costs and the mass of buildings, improvement of technical characteristics of structures, serviceability, strength, deformation, thermal insulation, operational properties, etc. The advantage of composites include: the construction of structures, elements and details with predetermined properties that meet working conditions and requirements. The variety of fibers and matrix materials, as well as the optimization of reinforcement schemes used to create the composite structures, give the engineers complete freedom to adjust the properties of the composite material accordingly at the expense of changing the component ratio and macro-structure. Hundreds of thousands of natural (non-composite) and artificial materials are now known. However, they can no longer meet the increased demands.

KEYWORDS:
composite; Georgian basalt; armature

1. Introduction

Fiber reinforced polymer composite (FRPC) is a composite material consisting of a binder (synthetic polymer) and reinforcement (fibrous fibers). The idea of replacing steel reinforcement with composite material appeared in the 1950s due to the following reasons:
– The start of a massive global construction of buildings that had to work in an aggressive environment;
– The trend of complex high-tech construction projects that required high strength of the structure and lightness at the same time;
– The sharp increase in the demand and price of steel in the world market (due to the impoverishment of existing iron ores) and the shortage of steel and other metals (alloying elements) led to the need to create other non-metallic alternative materials.

Composite reinforcement is based on a polyester or epoxy resin matrix reinforced with glass, basalt, carbon or aramid fibers. The composite material is inhomogeneous on the microscale, but homogeneous on the macroscale. The property of the material is determined by the constituent components, fibers and matrix. A typical multilayer FRPC consists of several million fine filament

[1] Georgian Technical University, Faculty of Civil Engineering, Tbilisi, Georgia, e-mail: t.khmelidze@gtu.ge, orcid id: 0000-0002-4430-8811
[2] Georgian Technical University, Faculty of Civil Engineering, Tbilisi, Georgia, e-mail: vako_kikadze@mail.ru, orcid id: 0000-0003-4050-9103
[3] Czestochowa University of Technology, Faculty of Civil Engineering, ul. Akademicka 3, 42-218 Częstochowa, Poland, e-mail: marlena.rajczyk@pcz.pl, orcid id: 0000-0002-4893-0931

fibers. The polymer matrix (resin) protects the fibers from mechanical damage, ensures uniformity and distributes loads between the individual fibers of the composite. Fibers used in composites bear more stress than steel and work practically until failure as a perfectly elastic material (obeying Hooke's law) [1].

The most common types of composite reinforcement in modern construction spaces are minacomposite (minaplastic), basaltcomposite (basaltplastic), carboncomposite (carbonplastic), non-modcomposite (aramidplastic) and combined reinforcements. The production of basalt composite reinforcement (Fig. 1) has been successfully carried out for more than 10 years in Georgia (Rustavi city, Basalt Fibers company) and the manufactured products are mainly supplied to Western European countries. The nomenclature of the released products is: rebar with a diameter of 4-28 mm, rebar mesh, chopped fiber, geogrid, tape and qecha.

Fig. 1. Basalt composite reinforcement

Interest in basalt is driven by three main reasons. The first – strength, hardness, resistance to temperature changes and aggressive environment and the characteristics of basalt plastic exceed that of mina plastic; Second – the price; And third – the presence of a powerful base of industrial basalt deposits in Georgia.

Basalt is a widespread cainotype (healthy), fibrous structured, black (blue, greenish), basic volcanic rock [2]. It melts easily at high temperature (1150-1350°C) and is a source of basalt fiber – the main basis of basalt products. The chemical composition of basalt stone (according to the data of the "Basalt-Fibers" company, SAST 211398245-001-2016) is given in Table 1.

Table 1
Chemical composition of Georgian basalt composite reinforcement (research of "Basalt-Fibers" company)

No	Oxides contained in basalt	Content [%]
1	SiO_2	48-52
2	TiO_2	0.2-2
3	Al_2O_3	14-18
4	Fe_2O_3	7-11
5	MnO	≥ 0.2
6	MgO	3.5-8.5
7	CaO	8-11
8	Na_2O	2.5-6
9	K_2O	2.5-6
10	SO_3	> 0.2

Conducted theoretical and practical studies show that composite reinforcements will occupy a certain segment in the space of reinforced constructions. Moreover, with the funding of the National Cooperative Highway Research Program (NCHRP) in the USA, based on the conclusion of the Firm Transportation Research Board, it is possible to make reinforced concrete coils with basalt composite reinforcement provided that the adhesion between the reinforcement and concrete is increased, which in turn, will increase the pulling capacity of the coil.

2. Discussion

As mentioned in the introduction, there is a powerful enterprise manufacturing basalt--composite products in Georgia which together with other products, produces basalt-composite reinforcement, the widespread use of which is prevented in Georgia by the absence of a suitable corresponding Georgian standard. In order to correct this shortcoming, a group of professors from the Technical University of Georgia and the University of Technology of the Republic of Poland, together with the employees of the "Basalt-Fibers" company of the city of Rustavi, Georgia, as well as the Department of Economic Policy of the Ministry of Economy and Sustainable Development of Georgia and the National Agency of Standards and Metrology of Georgia, are working on the standard of Georgian basalt composite polymer reinforcement production. The standard is developed taking into account the main normative provisions which are given in the methodological part of the international standard test [3].

A product standard is a set of documents that provides for all the necessary aspects of safety assurance and operational characteristics, process (processes) or services of a specific product or group of products and which includes the scope of two or more technical committees or subcommittees, based on, as far as possible, the underlying and product group standards.

The standard to be developed establishes common technical conditions and applies to periodic profile composite polymer reinforcement (FRPC) which is used to reinforce conventional and prestressed building structures and elements which are operated in various degrees of aggressive environments and meet fire resistance and fire safety requirements [4, 5]. The standard does not apply to composite polymer smooth-surfaced and flexible rods.

In accordance with the requirements [3] of the standard, the following methods of testing composite polymer reinforcement were developed:

- method for determining nominal diameter,
- axial tensile test method,
- compression test method,
- cross-section test method,
- determination of the strength of adhesion to concrete,
- method for accelerated determination of alkali resistance,
- method for determining the maximum operating temperature,
- passport form.

At present, the corresponding standards of all eight methods for conducting laboratory tests of composite polymer reinforcement have been prepared in the Georgian language [6-14]. In the laboratory complex of the Technical University of Georgia, an area has been allocated for conducting experiments. Two hydraulic presses are in full readiness (they are equipped), a testing device for transverse cutting of composite reinforcement has been made and sample batches of composite polymer reinforcement (of different diameters) have been imported. The laboratory tests necessary for the preparation of the state standard of Georgian basalt-composite reinforcement have been started.

In the month of June 2023, laboratory tests of 10 mm and 16 mm diameter basalt plastic standard samples (Figs. 2-4) were carried out in the laboratory of the GTU complex in full compliance with the requirements of the standard. The results are given in Tables 2 and 3.

Fig. 2.

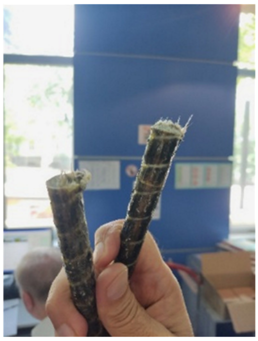

Fig. 3.

Fig. 4.

Table 2
Test results of 10 mm diameter basalt plastic reinforcement

No	Length ℓ [mm]	The normal diameter of the armature rod d [mm]	Cross-sectional area of the sample A [mm^2]	Breaking load P [N]	Ultimate shear stress τ_{sh} [N/mm^2]	Average value of shear stress τ_{sh}^{av} [MPa]
1	250	9.481	70.563	23100	163.68	169.82
2	250	9.481	70.563	26210	185.72	
3	250	9.481	70.563	24740	175.30	
4	250	9.481	70.563	22890	162.20	
5	250	9.481	70.563	22890	162.20	
6	250	9.481	70,563	23952	169,83	

Table 3
Test results of 16 mm diameter basalt plastic reinforcement

No	Length ℓ [mm]	The normal diameter of the armature rod d [mm]	Cross-sectional area of the sam-ple A [mm^2]	Breaking load P [N]	Ultimate shear stress τ_{sh} [N/mm^2]	Average value of shear stress τ_{sh}^{av} [MPa]
1	250	15.398	186.122	66380	178.32	175.99
2	250	15.398	186.122	68730	184.64	
3	250	15.398	186.122	64930	174.43	
4	250	15.398	186.122	63140	169.62	
5	250	15.398	186.122	64370	172.92	
6	250	15.398	186.122	66520	176.01	

3. Conclusion

The creation of the state standard of Georgia on the use of composite polymer reinforcement in concrete constructions is an important state matter and it will undoubtedly have a positive effect on the economic development of the country.

As a result of the tests, the limit of strength of 10 mm and 16 mm diameter basalt plastic reinforcement in transverse cutting were 169.82 MPa and 175.99 MPa, respectively.

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Badania zbrojenia bazaltowo-kompozytowego produkcji gruzińskiej przygotowanego w standardowy sposób

STRESZCZENIE:
Analizując rozwój współczesnego budownictwa, wyraźnie widać stały wzrost udziału konstrukcji nośnych i osłonowych wykonywanych w oparciu o materiały budowlane otrzymywane z wykorzystaniem nowej technologii. Kompozyty na bazie polimerów zajmują szczególne miejsce w tej gamie materiałów. Zastosowanie materiałów kompozytowych w budownictwie może rozwiązać ważne problemy, takie jak: zmniejszenie kosztów eksploatacji i masy budynków, poprawa właściwości technicznych konstrukcji - użyteczności, wytrzymałości, odkształceń, izolacyjności termicznej, właściwości eksploatacyjnych itp. Zaletą kompozytów jest: swoboda w konstruowaniu elementów i detali o określonych właściwościach, spełniających warunki i wymagania pracy. Różnorodność włókien i materiałów osnowy, a także optymalizacja schematów zbrojenia stosowanych przy tworzeniu struktur kompozytowych dają inżynierom pełną swobodę w zakresie odpowiedniego dostosowywania właściwości materiału kompozytowego kosztem zmiany proporcji składników i makrostruktury. Obecnie znane są setki tysięcy materiałów naturalnych (niekompozytowych) i sztucznych. Nie są one jednak w stanie sprostać rosnącym wymaganiom przemysłu i gospodarki.

SŁOWA KLUCZOWE:
kompozyt; bazalt gruziński; armatura