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THE EXPERIMENTAL AND THEORETICAL RESEARCH RESULTS FOR POSTS AND PIPELINES COMPOSED BY MULTI-TUBES MADE OF BASALT FIBER

Summary. Structural materials reinforced with basaltic fibers represent particular interest for building industry. These materials (such the: basaltic-plastics, concrete reinforced with basaltic-plastic bar reinforcement, basaltic fibrous concrete etc.) combine high physical-chemical and mechanical significance with relatively small density. Creation new types of pipes and pipelines on the basis of basaltic fibers, first of all is connected with using of composite materials reinforced with fibers. Application of basaltic fibers as a reinforcing material is one of the perspective directions not only for nowadays but also for future as well.

Keywords: basalt fiber, reinforced, concrete, pipe, pipeline, composite, material, compression, flexure, natural experiment, glass fibers.

1. Introduction. The unbroken glass fibers are used as a reinforcing agent in many countries of the world in production of composition materials and in light industry.

The development of their production is delayed mainly because of the increasing lack of raw materials (calcinated soda, boric acid, soleplate etc.) and because of the high technical requirements.

Some technological processes for receiving unbroken fibers from widely-distributed igneous basalt rocks, which require no additional processing, are worked out at present.

There are some quarries in Georgia, near Tbilisi (regions of Marneuli, Kaspi, Aspindza, Bakuriani etc.), where the raw materials contained rare and rare-earth metals can be found for receiving high quality fibers. The volume of these materials is estimated at tens of millions cub. meters.

Basaltic fibers as a reinforcing material are strong, stable for aggressive force and durable. Using basaltic fibers, it is possible to create some source saving technologies for light industry, building and other fields (machine construction, aviation, ship-construction etc.).Here is a list of qualities of basaltic fibers and products made of them:

- stableness for corrosion (12-5 times more than metals);
- frost- and heat-resistance (-265°C ÷ +900°C);
- almost incombustible (become charred when t = (1000 ÷ 1100)°C);
- non toxic;
- high durability showings (σ = (1900 ÷ 2400)MPa when the diameter of a fiber is (9 ÷ 12) mcm);
- construction elements are sometimes 3-10 times stronger, than analogous traditional constructions made from steel and concrete);
- lightness (decrease the weight of construction elements 5-20 times);
- do not create hindrance for radio and television waves and are dielectrics;
- heightened water resistance;
- when are plated with polyethylene, meet hygienic requirements of food industry;
- when fibers are received as a mineral wool, meet the requirements to be raised to heat-insulating materials.

Structural elements made with using basaltic fibers is protected I have by patent №SU 1830405, №P1755, №AP2162A, №AP2000 003937 and №U493, by St. committee on inventions and Discoveries of the USSR and Georgia “**Sakpatenti**”. These structures should be effectively used by construction of earthquake-resistant buildings, because these materials are very durable and light.

One of the perspective directions of application of basaltic fibers as bundled basaltic threads, which were saturated with polymer bonding adhesive, is manufacturing on their basis basaltic-plastic pipes of various diameters and destinations.

Approximate value of mechanical tensile strength such pipes at 20°C may be (12000 ÷18000) kg/cm^2 and essentially depends on composition and percentage ratio of bonding adhesive in manufactured articles (that for pipes usually puts together (5÷8)%). Physical-mechanical characteristics these pipes varies between following limits:

- density of articles – 1.9÷2.2 t/m^3;
- modules of elasticity at 20°C – ($5.5\cdot10^5 \div 10^6$) kg/cm^2;
- coefficient of linear expansion – $(0.5\div0.7)\cdot10^{-7}$ $degr.^{-1}$;
- mastered technology line of basaltic-plastic pipes production permits to manufacture pipes, which are able to stand pressure of about 2000 atmosphere and thermal loading about 800°C;
- interval of melting points – (1460÷1500)°C (at 1250°C fibers begin to be carbonized);
- color of articles is changed from dark-black to light-brown in dependence upon a kind of bonding adhesive and it is not necessary to work up in addition a surface of pipes;
- basaltic-plastic pipes are 3.5-4 times lighter than the steel ones and they do not need to be controlled with special and expensive methods for finding micro-cracks in their walls

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Basaltic-plastic pipes especially efficiently should be used for constructing of gas or oil pipeline and actually for transporting any kind of aggressive liquids or gases, thanks to their high strength and stability against on aggressive surroundings. They also can be wide applied for heating and hot-water-supply systems, for constructing of towns sewerage nets, air ventilation ducts, smoke stacks, refuse chutes etc.

Such a broad use of basaltic -plastic pipes is caused, because they give possibility to increase noticeable a service life of pipelines, which quickly go bad in consequence of steel corrosion. Using basaltic fibers for reinforcing of structural materials, among others for pipes of different destinations and diameters, is very perspective for many fields of industry. Scales and objects of their use may be highly diverse. First of all it is conditioned by originality of physical-mechanical and chemical characteristics of basaltic fibers.

Basaltic-plastic pipes reinforced with basaltic fibers are distinguished by high: strength, firmness to aggressive affects and durability.

Experimental examples of pipe structure elements in our researches had a casing envelope reinforced with standard aluminum-boric-silicate and basaltic (d=9÷12 mcm) unbroken fibers in the form of bundled threads. As a bonding adhesive was employed epoxy-polyether, which was hardened at a temperature T=18÷20°C.

The experiment was conducted with the purpose of establishment of virtual strength and deformation characterizations for pipe structure elements, which are under loads of compression or flexure.

2. Experiments of Axial Compressionє. For full revealing of axial compression characteristics, experiments was executed on a support elements of various height: 1.0 m, 2.0 m, 4.5 m and 7.0 m (Table 1, point 7). Supports 1 and 2 meters in height were tested in hydraulic press; supports 4.5 meters in height were tested in horizontal state with application of hydraulic jack; and 7 meters high support elements were tested with the help of a special making test bed. [*The exhaustion of bearing ability on compression of support of height 4,5 and 7,0 м is characterized by sharp loss of stability at critical loadings. After removal of compressing loading of a support come back in an initial rule (situation) without outside seen attributes of destruction. The diagram of dependence bearing ability on the central compression of support (BA-7,8,9,10) of different heights are resulted in a fig. 1.*]

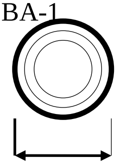
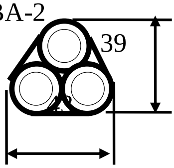
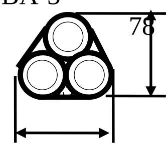
The test of examples was carried out by monotonous increasing in steps loads in a following sequence:

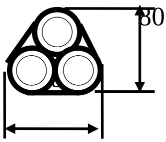
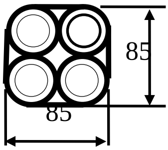
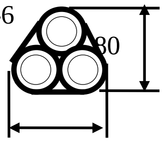
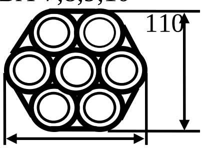
- for 1 meter high supports – 5 ton;
- for 2 meters high supports – 3 ton;
- for supports 3 and 4.5 meters in height – 0.5 ton;
- for supports 7 meters in height – 0.25 ton.

Table 2 shows load carrying capacity of compression, values of relative lateral strain and corresponding deflections, which have been obtained for supports of various height. Figure 1 shows dependence between height and load carrying capacity of supports.

3. Experiments of Flexure. Physical-mechanical and geometrical approximate characteristics of test examples of beams are shown in table 1, points 1÷6.

Table. 1.
Sizes and materials

N	Number of example, type and sizes of cross-section, material of pipe	Characteristics of pipe materials						Fiber type and exp., gr	Weight of article 1 mlong, kg
		E	t	Rc	D	d	L		
		MPa	MPa	MPa	mm	mm	mm		
1	2	3	4	5	6	7	8	9	10
1	BA-1  Polypropylene	3500	90	45	40	35	2500	500 Basaltic -fibers	1.15
2	BA-2  Glass-fibers	5000	245	98	20	15	240 0	650 Basal tic- fibers	1.82
3	BA-3  Polypropylene	3500	90	45	40	35	240 0	850 Basal tic- fibers	1.75

4	BA-4  Glass-fibers	5000	245	98	40	35	240 0	800 Basal tic- fibers	4.1
5	BA-5  Glass-fibers	5000	245	98	40	35	420 0	1500 Glass - fibers	5.6
6	A-6  Glass-fibers	5000	245	98	40	35	420 0	1600 Basal tic- fibers	1.0
7	BA-7,8,9,10  Glass-fibers	5000	245	98	40	34	1000 2000 4500 7000	300÷ 2100 Glass - fibers	6.6

Test process foresaw two variant:

1. For cantilever beams (Table 1, points 1÷4);
2. For one-, two- and three-span beams (Table 1, points 5 and 6).

Experimental testing of structures has taken place at a special test bed made in TbilZNIIEP. Distributed load was put on the beams in steps. Maximum value of distributed loads were: q=5.4 kg/cm for one- and two-span beams, and q=6.3 kg/cm for three-span beams. Each next step of load stayed on 10 minutes and then was fixed reading of devices on this step of load.

During unloading of beams was noticed a mechanism of effects of permanent deformation. These effects were continued a short time and permanent deformations completely were disappeared for these limits of loads in 5-6 minutes after its taking off.

The results of beam tests are shown at the figures 2 and 3. Results of computer analysis by “LIRA CAD 2012” are show at annex-1.

4. About Behavior of Pipes under Loads during a Long Period of Time. The plan of experiments did not foresee to load of beams to condition of destruction (with dynamic, cyclic and long duration loads at a various temperature regime), but these kinds of experiments is an object of further special investigations.

Structure elements like above-examined must be evaluated not only on the basis of its behavior at the short duration loads. The strain capacity of these structures must be determined with taking into consideration effects of action on real conditions of long duration loads.

It is able to forecast a long duration deformability of elements by means of mathematical modeling of structures. One of the ways to solve this problem can be expressed by the following expression on the basis of [2,4,5]:

$$\varepsilon_{total} = \varepsilon_{elastic} + \varepsilon_{plastic} + \varepsilon_{flow} . \qquad (1)$$

The stress in such structures

$$\sigma = E(t)\cdot\varepsilon_{total} , \qquad (2)$$

where E(t) - modulus of deformation at a certain period of time.

Table. 2.

Results of natural test of the tube type elements.

Glass-plastic pipes bound with glass-plastic casing envelope (Example BA-7) Height, Number of m support		**Load carrying capacity, ton**	**Deflectionsf , mm**	**Relative lateral strain, ε**
1	2	3	4	5
1.0	1 2	85.0 80.0	--- ---	0.0085÷0.0105
2.0	1 2	40.0 45.0	11.9 11.0	0.0062÷0.0071
4.5	1 2	6.5 7.0	72.8 80.0	0.0037÷0.0046
7.0	1 2 3	3.25 3.0 3.2	142.2 76.2 97.6	0.0019÷0.0022

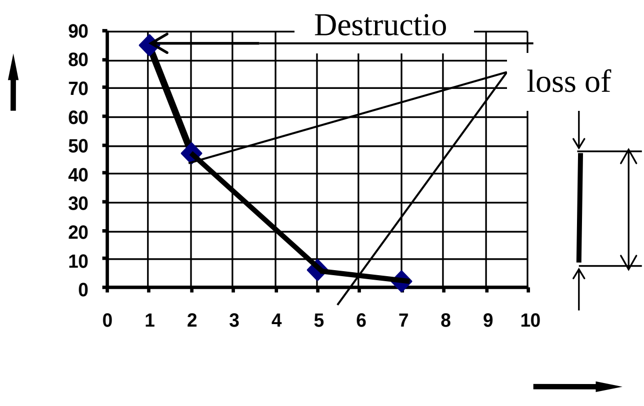


Fig. 1. Diagram of dependence between height and load carrying capacity of support.

Determining of elastic, plastic and flow deformations are usually realized on a basis of corresponding analytical, numerical, experimental researches and modeling. By means of these data can be established a prognosis of structure behavior under loads during a long period of time.

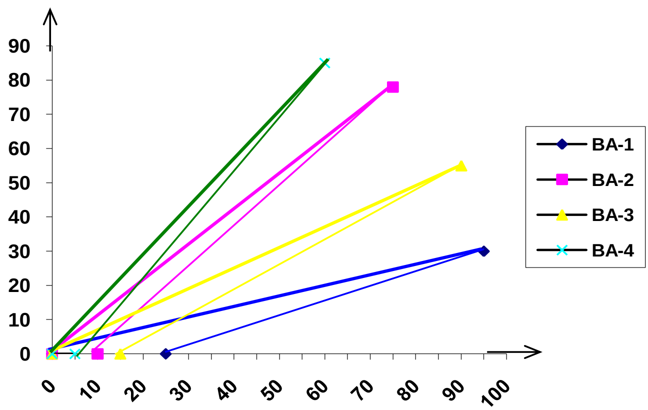


Fig. 2. «Load-deflection» dependence for cantilever beams (by taking into consideration residual strain).

Conclusions. Taking into consideration results of experimental investigations it is possible to conclude:

1. Carrying capacities of basaltic plastic beams and supports under short duration loads are high enough and they with confidence may be used instead of steel, aluminum, wooden and reinforced concrete structures. They also may be used for pipes of various diameters and destinations, i.e. also for any kind of pipelines.

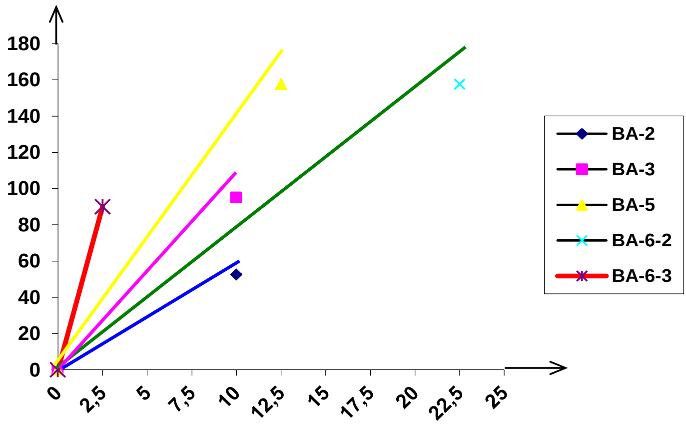


Fig. 3. «Moment-deflection» dependence for middle of the span of the beams.

2. Flexure of structure elements made up from pipes connected together with basaltic plastic envelope is characterized with slip between touching surfaces of component pipes, that evokes increasing of total deformations.
3. Above-mentioned structure elements have high specific strength and flexibility that is necessary to foresee in design process.
4. Increasing deformation in time such structures is also necessary to foresee in design process, otherwise it may evoke serious emergencies.
5. Structure elements like above-mentioned ones may be used as pipes of various diameters, from which may be constructed pipelines of various destination for any region.

ANEX-1 Results of computer analyses.

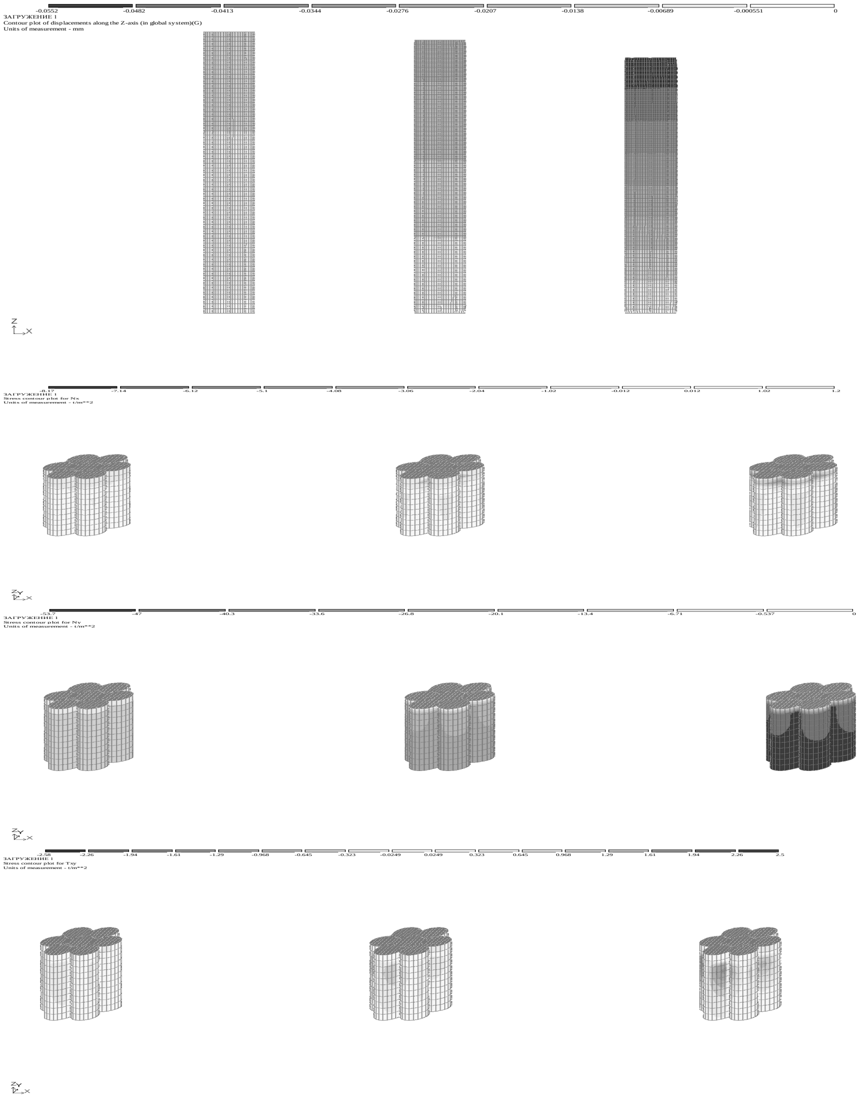


Fig. 4. results of computer analysis (deflections and stresses) of tube type elements using computer program LIRA CAD 2013

References

1. Гигинейшвили Д.Я., Береговой Г.Л. Численное моделирование и экспериментальные исследования напряженно-деформированного состояния элементов строительных конструкций в зонах анкеровки с неметаллической арматурой./ Тезисы докладов 5 всесоюзной конференции по статистике и динамике пространственных конструкций. - Киев: КИСИ, 1985г.

2. Гигинейшвили Д.Я. Численно-аналитический метод потенциала для расчета конструкций из композиционных материалов с учетом разрушений./ Теоретична и прокладна механика. Шести национален конгресс по теоретична и проиложна механика. Варна - 1988г. - София: БАН, 1985г., Книга 2, с.35-38.

3. Veryuzhsky Yu., Gigineishvili J. Design of the Quick-rise Buildings for Mountain Area. IDEEA One. First International Design for extreme Environments Assembli. USA. Houston, 12-15.11.1991.

4. Yu. Veryuzhsky., J. Gigineishvili. Numerical modeling of design and technology of construction in yhe extreme states. Metod of potentials and finite elements the in automatic research of engineering structures. Kiev: ZNANIE.1991.

5. J. Gigineishvili, V. Gavrilenko. Peculiarities of distributive stress in joint of non-welding connections of constructions. Metod of potentials and finite elements the in automatic research of engineering structures. Kiev: ZNANIE.1991.

6. Yu. Veryuzhsky, J. Gigineishvili, A. Snitko. Numerical modeling, dissain and technologi of structuries for extreme environments. Metods of potential and final elements in she automated researches of engineering designs. The theses of the reports International of conferences. Academi of Siense Russian Federation the House of the scientist. St/ Petersburg. 1996. Peges 26-27.

7. J. Gigineishvili, I. Mgaloblishvili. Technologikal line of production of SAKPATENTI. NP 2000. Tbilisi:.2001.

8. J. Gigineishvili, G. Chikvaidze. Pipes and pipe-line structuries. SAKPATENTI. NP 2930. Tbilisi:.2001.

9. J. Gigineishvili, L. Dvali, T. Matsaberidze, D. Gigineishvili, SAKPATENTI. P5185. Tbilisi:.2011.

10. Программный комплекс ЛИРА-САПР 2013. Учебное пособие: Электронное издание. 361 стр. 2013г.

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