Appliance of basalt fiber based materials in building and anti-seismic constructing. Investigations results, conclusions and experience of basalt continuous fiber (BCF) based materials in building

The Article is dedicated to appliance in building of reinforcing agents and composite materials based on BCF: chopped basalt continuous fiber for reinforcement of concrete and concrete frames, building and road nets, basalt-plastic reinforcing rods (rebar) and composite materials.

The Article displays researches results and recommendations of leading scientific research institutions of Ukraine: SRI of Building Constructions, Shulgin State Road SRI [Ukraine]; SRI of Steel Concrete, Union Road SRI and Russia Road SRI [Russian Federation]; China SRI; Sherbrooke Lab of Canada University, SRI for Seismology and Anti-seismic Constructing of the Academy of Sciences of Tajikistan, for appliance of BCF-based materials for building, roads constructing and anti-seismic constructing. Works on research and appliance of BCF materials for building and roads constructing are executed during several years, starting from 2000, and it proved effectiveness of such materials appliance in roads constructing practice.

It is well known that basalt continuous fiber made from basalt has sufficiently high strength characteristics, chemical and thermal stability [1, 2, 3]. That’s why BCF provides required characteristics and quality of reinforcing, geo-textile and composites for building and roads constructing. Appliance of BCF-based reinforcing, geo-textile and composite materials in anti-seismic building and roads constructing allows improving seismic stability of buildings and constructions, and also road and road surfaces against damages from earthquakes and environments, increasing of buildings seismic stability and roads lifetime and main time between repairs, decreasing of materials consumption during roads constructing and repair.

According to building and roads constructing practice, chopped fibers are used for reinforcing of concrete frames and asphaltic concrete road surfaces; also use geo nets, basalt-plastic rebar, binding stripes and flat reinforcing rods. It is perspective to apply widely the composite materials: constructing shapes, composite constructions and reinforced concrete frames for buildings, constructions, bridges, tunnels.

Reinforcing of concrete base and load-carrying structures of buildings, asphaltic concrete and roads surfaces with chopped fibers (chopped BCF)

Adding of chopped basalt fibers provides volumetric reinforcing of concretes and asphaltic concretes. Reinforcing of concretes and asphaltic concretes was previously done using steel fiber, cellulose and other fibers. Basalt chopped fibers have a high stability against influence of environment, temperature differences, intensive loads, and alkaline conditions. Basalt fiber doesn’t undergo the corrosion, and has 2-2.5 times higher strength characteristics in comparison with steel fiber.

Advantages of basalt fiber for reinforcing: it has high strength; it is not stretched under influence of load; it has chemical, corrosion and thermal stability against influence of environment, temperature differences, intensive loads; it is not expensive. Those advantages open possibility of BCF wide appliance for reinforcing of concretes and asphaltic concretes in anti-seismic and roads construction.

Elementary fibers (filament) with diameters 13-18 microns (Photo No.1) are evenly distributed in all directions by full volume of concrete or asphaltic concrete (Picture No.1). In this case each 1 cm$^3$ of concrete or asphaltic concrete contains several tens of elementary cut fibers. It is obvious that, in case of such volumetric reinforcing with BCF, concretes and asphaltic concretes substantially improve its flexural strength and compressive resistance, and roads surfaces improve its shock resistance, crack growth resistance, loads resistance and operation lifetime period.

Basaltic fiber is already widely used, and proved it high effectiveness during manufacturing of floors in buildings, stores, trade centers, industrial areas.
Photo No.1: Chopped BCF (basalt fiber).
Diameter of filament is 16 microns;
length 12 mm

Picture No.1: Volumetric reinforcing of concretes and asphaltic concretes

Concretes strength improvement depends on quantity and length of inserted fiber. Research of concretes strength, reinforced with BCF, depending on quantity and length of inserted fiber, is already executed. Concrete strength was received by results of testing, which was executed in accordance with State Standard GOST 10180-90 (concrete tensile strength during its bending) [4].

![Diagram of concrete strength improvement after reinforcing with BCF of 15-16 microns in diameter and length 12mm (green color), 24mm (red color) and 50mm (blue color) [4].](image)

Analysis of research results shows that BCF (24 mm) is the most suitable for concretes reinforcing. Generalization of research testing results shows that content of BCF (24 mm) should be 2-3%. BCF is dozed in percentage ratio to weight of dry mix (cement and sand). In conditions of such reinforcing of concrete (type B20), its tensile strength (axial and during its bending) is improved in 1.79-2.24 times, and is accompanied with transition into plastic destruction [4].

BCF may be widely used for reinforcing of reinforced concrete items for anti-seismic, road and hydraulic building: trays, flumed aqueducts, pipes, wells, reinforced concrete ties, rod filler members and constructions.

Anti-seismic building applies lighted building materials (gas concrete and foam concrete). Reinforcing of gas concrete and foam concrete with BCF allows improving its strength for compressing
in 1.2 times, flexural strength in 1.25 times, and its crack growth resisting. Research on gas concrete and foam concrete reinforcing with cut BCF was executed by Belarus SRI for Building Construction.

Shulgin State Road SRI [Ukraine] has executed research and physical-mechanical testing of concrete and asphaltic concrete road surfaces reinforced with BCF. In accordance with executed tests, appliance of basalt fiber for reinforcement of concrete constructions and asphaltic concrete road surfaces allows improving its strength for compressing on 37-40%, flexural strength – on 100-150%, and improving of fracture strength of road surfaces.

Conclusions by the results of testing of concrete and asphaltic concrete road surfaces reinforced with BCF (executed by Shulgin State Road SRI, Ukraine, in 2010) [5].
1. Research on determination of possibility to use BCF for volumetric reinforcing of cement concrete and asphaltic concrete mixtures has shown that chopped BCF may be used as reinforcing additive for improvement of physical-mechanical features of pavement.
2. Injection of BCF into concrete allows improving of its physical-mechanical characteristics (strength for compressing on 20-30%, flexural strength – on 120-125%, frost resistance and water resistance – on 15-20%).
3. Research determined optimum quantity of BCF according to weight: for cement concrete – 2.0%, for cold and hot asphaltic concrete – 1.0% from quantity of mineral powder. Technology of BCF insertion has mostly no influence on concrete physical-mechanical characteristics. Matched mixes completely correspond to requirements of State Standard in Ukraine DSTU BV.2.7-89-99 and DSTU BV.2.7-119-2003, and these mixes are optimal for usage.
4. Improvement of physical-mechanical features of road surfaces is indicating positive influence of basalt fiber on structure of concretes and asphaltic concretes.

Research works on implementation of chopped BCF were executed in Union Road SRI and Russia Road SRI [6], which confirm conclusions on effectiveness of applying of volumetric reinforcement of road surfaces. They developed recommendations on applying of BCF for reinforcing of road surfaces during construction and repair of highways.

Basalt-plastic reinforcing rods - rebar (BPR), shapes and composite items for anti-seismic building

BPR is used for reinforcing of concrete frames, buildings and constructions, tunnels, bridges. At the same time, BPR strength properties are better than steel rods properties in 2-2.5 times, and don’t undergo to corrosion. BPR complex testing was done in SRI of Concrete and Steel Concrete, State Road SRI of Ukraine, SRI of Building Constructions, China SRI, Canada Lab [8, 9, 10].
China and Ukraine are already approved the state standards for usage of composite BPR, standards approval in Russia is also finished.

Table No.2 shows the results of testing on replacement of steel rods with composite BPR.

<table>
<thead>
<tr>
<th>No.</th>
<th>Composite BPR</th>
<th>Qty of running meters in 1 ton</th>
<th>Full-strength replacement with steel rods, Ø (mm)</th>
<th>Qty of running meters in 1 ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BPR -4, Ø 4</td>
<td>48780</td>
<td>6 AIII, Ø 6</td>
<td>4504</td>
</tr>
<tr>
<td>2</td>
<td>BPR -6, Ø 6</td>
<td>20618</td>
<td>8 AIII, Ø 8</td>
<td>2531</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>10 AII, Ø 10</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>BPR -8, Ø 8</td>
<td>11299</td>
<td>AIII 12, Ø 12</td>
<td>1126</td>
</tr>
<tr>
<td>4</td>
<td>BPR -10 Ø 10</td>
<td>7092</td>
<td>14 AIII, Ø 14</td>
<td>826</td>
</tr>
<tr>
<td>5</td>
<td>BPR -12 Ø 12</td>
<td>4897</td>
<td>16 AIII, Ø 16</td>
<td>632</td>
</tr>
<tr>
<td>6</td>
<td>BPR -14 Ø 14</td>
<td>3788</td>
<td>20 AIII, Ø 20</td>
<td>405</td>
</tr>
</tbody>
</table>

Replacement of traditional steel reinforcing rods with basalt-plastic rods shall reduce the price on 20-30%.

Special anchors with holes were developed for fastening of tunnels (Photo No.8).

Anchors are made of hollow rods. Hollow rods are filled with concrete mixes, which are fastening the anchors during construction of tunnels, and fastening of mine working areas.

Constructional ribbons and BCF woven rowing fabrics are used for increase of seismic stability of buildings, bridges and constructions. Ribbons and construction fabrics are preliminary impregnated with binding agents (so called preps). Buildings are subjected to coverage by preps. After that the preps are polymerized to achieve strength necessary for improvement of buildings and constructions (instead of framing and strengthening of buildings with steel constructions).
Composite materials and items are containing 75-78% of BCF in its composition, and this is the basement of its composite materials strength.

Main Conclusions:
1. Materials, which are based on basalt fiber, by reason of its characteristics and price, nowadays find wide application in usual and anti-seismic constructions.
2. Appliance of BCF materials allows substantial increasing of quality, physical-mechanical and operational characteristics, and lifetime of asphaltic concrete and concrete road surfaces.
3. Appliance of composite materials and items, which are based on basalt fiber, has a great future in anti-seismic constructing.

**BCF reinforcing constructing and road nets**

BCF constructing and road nets (Photo No.12, 13) are used for reinforcing of walls, plasters, and in the capacity of masonry nets.

<table>
<thead>
<tr>
<th>Description, (cell size)</th>
<th>Density, g/m²</th>
<th>Breaking load, N</th>
<th>Appliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>GBF-25W (25x25 mm)</td>
<td>400+-10%</td>
<td>1200 900</td>
<td>Reinforcing of roads and masonries</td>
</tr>
<tr>
<td>BFN-5 (5x5 мм)</td>
<td>85+-8%</td>
<td>860 920</td>
<td>Reinforcing of walls during plastering and finishing works</td>
</tr>
<tr>
<td>BFN-10 (10x10 мм)</td>
<td>135+-8%</td>
<td>1260 1380</td>
<td>Reinforcing of walls and masonries</td>
</tr>
</tbody>
</table>
Reinforcing constructing material, manufactured using BCF, may sustain high loads, temperature differences, it is not stretched under loads, and it has high chemical stability and long-time operation.

Appliance of BCF-based reinforcing materials allows improving anti-seismic stability of buildings and constructions, decreasing of materials consumption and constructing price in active seismic areas.

BCF-based reinforcing constructing and road nets have a nice prospect of wide appliance in roads and hydraulic engineering construction, during re-vegetation and erosion protection of soil, during execution of works on protection against landslide, and others.

On the basis of executed scientific research and innovation works on development and appliance of BCF-based geo-textile materials, we can make the following conclusions:

1. BCF is a nice substitute of made-of-steel reinforcing materials, it has high strength, chemical and thermal stability, it is not stretched under loads, and it has long-time operation.
2. BCF-based reinforcing materials are showing high stability in wet and alkaline environment, and this feature opens wide prospective of its implementation in reinforcing of concrete frames.
3. Appliance of BCF-based reinforcing materials and cut basalt fibers allows creating of reinforced constructing frames for road and hydraulic engineering constructions.
4. Appliance of BCF-based reinforcing materials has nice prospect of wide appliance in roads and hydraulic engineering construction.
5. BCF-based composite materials, due to its characteristics and price, are actively excluding steel materials in machinery and other branches. And it is possible to apply BCF-based composite materials in building, roads and hydraulic engineering construction in active seismic areas.

Publication
2. В.Н. Деревянко и др. Стойкость базальтового волокна в различных средах.
3. Оснос С.П. Основные характеристики базальтовых волокон и области их применения. Композитный мир. basaltm.com
4. Заключение по результатам испытаний прочности на растяжение при изгибе бетона армированного базальтовой фиброй производства ТОВ «Технобазальт». НПП «Будконструкція» Ю.А.Климов, Киев, 2009 г.
5. Экспертное заключение об определении возможности применения базальтовой фибры различных типов для дисперсного армирования цементобетона и асфальтобетона. ДерждорНИИ, 2009 г.
6. Технические условия ПСВ-Д. ТУ У 6 00209775.070.. Полотно сетчатое базальтовое для дорожного строительства Украинский центр стандартизации и метрологии, 2000 г.
7. Арматура неметаллическая композитная периодического профиля. ТУ 5769 – 248 – 35354501 – 2007. Разработано НИИ Бетона и Железобетона, Москва, РФ.
7. Технические рекомендации по применению неметаллической композитной арматуры периодического профиля в бетонных конструкциях. НИИ Бетона и Железобетона. Москва, 2004 г.
8. Экспертное заключение о возможности использования арматуры композитной базальтопластиковой АБП для армирования бетонных изделий. ГосдорНИИ Украины, 2009 г.
9. Physical, Mechanical, and Durability Characteristics of Basalt FRP (BFRP) Bars Preliminary Test Results, Canada, Universite De Sherbrooke, April, 2010.
10. ДСТУ – Н Б В.2.6-185:2012 Настанова з проектування та виготовлення бетонних конструкцій з неметалевою композитною арматурою на основі базальто- і склеровингу.