Applianceman of basalt fiber based materials in road building. Investigation results, conclusions and experience of application

The Article is dedicated to appliance in building of reinforcing agents and composite materials based on BCF: cut fiber for reinforcement of concrete and concrete frames, building and road nets, basalt-plastic reinforcing rods 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 based continuous fiber has sufficiently high strength characteristics, chemical and thermal stability. That’s why BCF provides required characteristics and quality of reinforcing, geo-textile and composite materials 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, building and road nets, basalt-plastic reinforcing rods, 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 basalt fibers

Adding of chopped 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 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 cm³ 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 strength for twisting and compressing, 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.
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 ГОСТ 10180-90 (concrete strength for stretching during its twisting).

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 strength for stretching (axial and during twisting) is improved in 1.79-2.24 times, and is accompanied with transition into plastic collapse [4].

BCF may be widely used for reinforcing of steel concrete items for road building: trays, pipes, wells, steel concrete railway sleepers, traffic lane separating constructions and fencing constructions.

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%, for twisting – on 100-150%, and improving of crack growth resistance 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 road surfaces.

2. Injection of BCF into concrete allows improving of its physical-mechanical characteristics (strength for compressing on 20-30%, for twisting – 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 ДСТУ Б.2.7-89-99 and ДСТУ Б.2.7-119-2003, and these mixes are optimal for usage.

4. At preparation of hot asphaltic concrete it is better to supply basalt fiber to the mineral material (powder), subsequently mixing it with bitumen. Preparation of cold asphaltic concrete mixtures is performed at 0 - 95-1000C with supply of fiber to the mineral part of the mixture and mixing during 4-5 minutes. After doing this bitumen is supplied, and mixing time makes up 6-8 minutes.

5. Input of basalt fiber into hot asphaltic concrete mixtures provides for crack resistance of surface (possibility of crack development and growth is decreased), as well as for creation of stable structure of asphaltic concrete against temperature fluctuations, which will also favour the increase of shift-resistance of asphaltic concrete. Thanks to disperse reinforcement, asphaltic concrete surfaces have high tensile strength at bending and high shift-resistance. It is possible to predict the extension of service life of road surface by 1.5 times.

6. Research of physical and mechanical properties of cold asphaltic concrete mixtures showed that cold asphaltic concrete mixtures reinforced with basaltic fiber do not become compressed and have extended pressure strength (by 70-80% more than reference cold asphaltic concrete mixtures). Water-resistance parameter is within the norm and more than in a standard mixture.

7. Improvement of physical-mechanical features of road surfaces is indicating positive influence of basaltic fiber on structure of concretes and asphaltic concretes. When fiber is mixed with bitumen, interface layers are created. They prevent from separation of bituminous binder from fiber surface and from water penetration during operation.

8. Another important factor is the possibility to apply cold asphaltic concrete mixtures reinforced with basaltic fiber for emergency road repair which is conducted in adverse weather conditions – low temperature and high humidity, in order to provide for faultless movement of transport during the year.

9. Economic effectiveness of materials disperse-reinforced with basaltic fiber takes place thanks to extending service life of road surfaces, possible decreasing the thickness of upper layer, as well as decreasing repair and maintenance costs.

10. Asphaltic concrete and cement concrete with adding of basaltic fiber can be recommended for application in production conditions in all road and climatic areas.

Research works on implementation of cut BCF were executed in Union Road SRI and Russia Road SRI, 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.

**Geotextile mesh of BCF (basalt continuous fiber) rovings.**

Road geotextile mesh of BCF (photo 2) are intended for reinforcing road asphaltic concrete surfaces in building and repair of asphaltic concrete roads, strengthening soil walls and road slopes. During road construction road mesh is laid between broken stone layer and asphaltic concrete layer, and during repair works it is laid between the layers of asphaltic concrete (photo 3).
BCF mesh were developed, produced and used for the first time in Ukraine during the construction of road sections (Lviv-Chop, Kyiv-Odesa) that are the most subject to deteriorating during operation, at public transport stops of buses and trolleybuses in Kyiv in 2001 – 2002 years [7]. These works were conducted by Ukrainian Research Institute of Road Construction and by Ukrainian Road Authority. Reinforcing of asphaltic concrete roads with mesh showed good results in operation starting from 2001.

In foreign practice geo-textile materials are made of chemical and optic fiber. Geo-textile road mesh based on chemical fiber have certain drawbacks: they are stretched under the impact of road load. Road mesh based on glass fiber do not have the required chemical resistance against environmental factors, alkalis and salts.

During operation road mesh undergoes considerable load, as well as the impact of salt solutions, and in concretes – the impact of alkaline condition. Characteristics of BCF mesh completely meet these requirements; they have the necessary strength, resistance against adverse conditions and environment, as well as long-term operation capacity.

BCF road mesh have a number of advantages as compared to their foreign counterparts (road mesh made of chemical and glass fiber): these are produced of natural raw material, they endure high loads and temperature fluctuations, do not stretch under load impact, have high chemical resistance and long-term operation capacity, and are non-combustible.

Advantages of BCF-based road mesh as compared to chemical fiber mesh: do not stretch under load, tolerate high and low temperatures and cost less by 2.5 - 3 times. If these are compared to glass fiber mesh – do not deteriorate under the effect of alkaline conditions and the environment and have more strength. BCF-based geo-textile materials have the most advantageous quality-price ratio, in comparison with other types of fiber.

In order to increase the strength, durability and quality of road surfaces, PSB-D road mesh was developed (PSB-D stands for basalt netlike fabric for road building TU Y 6 00209775.070), as well as NPB-550 fabric (NPB stands for complete thread-bonded basalt fabric 550 gr/m²) for road building in especially difficult geological conditions (swamp, landslides).

Principal technical characteristics of road meshes and fabrics based on BRF rovings are given in Table 1.

<table>
<thead>
<tr>
<th></th>
<th>PCB-D</th>
<th>NPB-550 K</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Breaking load, not less, kg</strong></td>
<td>Across width 120</td>
<td>Across width 600</td>
</tr>
<tr>
<td></td>
<td>Across length 120</td>
<td>Across length 600</td>
</tr>
<tr>
<td><strong>Density, gr/m²</strong></td>
<td>250±-10</td>
<td>550±-10</td>
</tr>
<tr>
<td><strong>Stretching under load, %</strong></td>
<td>1 – 1.5</td>
<td></td>
</tr>
</tbody>
</table>

Impregnation of mesh with special composition provides for its rigidity, non-combustibility, resistance against acids and alkalis.
The main purpose of these materials is road construction (see fig.1): reinforcement of road surfaces (PCB-D mesh is laid between breakstone and asphaltic concrete layers, NP-550K fabrics – between sand and breakstone layers).

Integrated testing of PCB-D road mesh based on BCF have been conducted by the Road Research Institute of Ukraine in road building practice since 2001. Geo-textile materials were used in building of highway section Kyiv- Odesa, Lviv-Chop. The effectiveness of using geo-textile materials was test-proven. Preliminary calculations, application practice and foreign experience show that the GM decrease the probability of cracks, saggings and pits on road surfaces, with that the repair interval of road surfaces is increased by 1.5 – 2.5 times.

![Photo 4. Road mesh application in building new roads.](image)

![Photo 5. Reinforcing earth walls with road mesh.](image)

Application of geo-textile reinforcing materials based on BCF in road construction allows to increase repair interval of road operation by 2 – 2.5 times, as well as to decrease material consumption for road building in complicated geological conditions.

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.

BCF net, which is placed and fastened on the ground, allows growing of grass, bushes and trees. Such method is the most effective, not expensive and corresponds to ecological requirements.

Customers of BCF geo-textile materials: roads and hydraulic engineering construction companies, specialized organizations that work with soils re-vegetation, landslide protection (open mines, ravines, waste banks, river banks reinforcing etc.) and other works.

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 good substitute of metal reinforcing materials, chemical and glass fiber, as they have high chemical and thermal strength, do not stretch under load and are durable in operation.
2. BCF-based reinforcing materials are showing high stability in wet and alkaline environment, under influence of environment, and this feature opens wide prospective of its implementation in reinforcing of concrete frames and roads asphaltic concrete surfaces.
3. Application of geo-textile reinforcing materials, made of cut basalt fibers, allows manufacturing of reinforced constructions, slopes, embankments etc., and providing of high quality of road construction.
4. Application of geo-textile reinforcing materials, made of cut basalt fibers, has a nice prospect of implementation in practice of road and hydraulic engineering construction in Ukraine.

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

BPRR is used for reinforcing of concrete frames, buildings and constructions, tunnels, bridges. At the same time, BPRR strength properties are better than steel rods properties in 2-2.5 times, and don’t undergo to corrosion. BPRR complex testing was done in SRI of Concrete and Steel Concrete, State Road SRI of Ukraine, SRI of Building Constructions, China SRI, Canada Lab.

China and Ukraine are already approved the state standards for usage of composite BPRR, standards approval in Russia is mostly finished.
Table No.2 shows the results of testing on replacement of steel rods with composite BPRR.

<table>
<thead>
<tr>
<th>No.</th>
<th>BPRR, Ø (mm)</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>BPRR -4, Ø 4</td>
<td>48780</td>
<td>6 AIII, Ø 6</td>
<td>4504</td>
</tr>
<tr>
<td>2</td>
<td>BPRR -6, Ø 6</td>
<td>20618</td>
<td>8 AIII, Ø 8</td>
<td>2531</td>
</tr>
<tr>
<td>3</td>
<td>BPRR -8, Ø 8</td>
<td>11299</td>
<td>AIII 12, Ø 12</td>
<td>1126</td>
</tr>
<tr>
<td>4</td>
<td>BPRR -10 Ø 10</td>
<td>7092</td>
<td>14 AIII, Ø 14</td>
<td>826</td>
</tr>
<tr>
<td>5</td>
<td>BPRR -12 Ø 12</td>
<td>4897</td>
<td>16 AIII, Ø 16</td>
<td>632</td>
</tr>
<tr>
<td>6</td>
<td>BPRR -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 openings were developed for fastening of tunnels (Photo No.8).

Photo No.8: Anchors with openings for tunnels fastening

Photo No.9: Composite BCF wire for cable-braced bridges
BCF-based composite materials, due to its characteristics and price, are actively excluding steel materials in machinery and other branches. That’s why the actual task is to use composite materials and items widely in roads constructing. Nowadays a large list of developed and manufactured samples of BCF-based composite materials for roads constructing already exists: composite wires for cable-braced bridges (Photo 9), illumination columns (Photo 10), collectors’ bodies, road signs, bump stops, covers for collectors and underground pipelines (Photo 12).

Photo 10: Composite columns for illumination and power lines

Photo 11: Composite construction of underground pipelines collector

Photo 12: Composite covers (replacement for steel or cast iron covers)

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 road 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 road constructing.