ISSN: 3030-3621
Ta'lim innovatsiyasi va integratsiyasi

CALCULATION OF THE USE OF BASALT REINFORCEMENT IN THE BENDING ELEMENTS OF THE BRIDGE STRUCTURE IN THE "LIRA SAPHIR" PROGRAM

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Annotation: This article investigates the structural advantages and application potential of basalt reinforced concrete (BFRC) beams in modern bridge construction. As a sustainable and high-performance alternative to traditional steel reinforcement, basalt rebar offers superior tensile strength, corrosion resistance, and thermal stability. The paper reviews recent scientific studies highlighting improved flexural and shear behavior of BFRC beams, including increased load-bearing capacity and delayed crack initiation. A sample flexural calculation is provided to illustrate the design approach based on typical material properties. The study concludes that BFRC beams are a promising solution for enhancing the durability and sustainability of bridge infrastructure, especially in corrosive environments.

Keywords: Basalt fiber; Reinforced concrete; Bridge construction; Flexural strength; Corrosion resistance; Sustainable materials; BFRP bars; Structural performance; Shear behavior; Composite materials.

Corrosion is a natural phenomenon. Like other natural hazards such as earthquakes, floods, or severe weather, corrosion can cause dangerous and costly damage to everything from automobiles, appliances, and drinking water systems to pipelines, bridges, and public buildings.

Corrosion of steel reinforcement is one of the most common structural failures in concrete, especially in severe weather conditions where de-icing salts are required or in structures located near sea water. The U.S. Federal Highway Administration (FHWA) has released a groundbreaking study titled "The Costs of Corrosion in the United States and Strategies to Prevent Them," which examines the direct costs associated with metal corrosion in nearly every sector, from infrastructure and transportation to industry and manufacturing. The study found that the total annual direct costs of corrosion in the United States are approximately $276 billion, or about 3.1% of the country's gross domestic product (GDP). In addition, the indirect costs of corrosion are conservatively estimated to be equal to the direct costs, which would put the cost of corrosion at $552 billion (or 6% of GDP). In addition, one in nine bridges that motorists in the United States cross each day reported some degree of deterioration. Nationwide, about 66,405 bridges, or 11.5%, are rated "structurally deficient" according to government standards. In Canada, the direct costs of corrosion are $23.6 billion, or 2–4% of global gross domestic product (GDP). Therefore, corrosion-resistant materials, environmentally friendly and as economically efficient as possible structures have become an urgent problem for civil engineers. The production of basalt reinforcement as a local raw material in our country also requires the formation of issues of its use in its place. That is, through the use of basalt reinforcement, it will be possible to improve the country's raw material base and achieve economic efficiency. As noted above, we need to form a regulatory framework for the widespread use of basalt reinforcement. The properties of basalt reinforcement, due to its resistance to adverse weather conditions, provide the possibility of using it as bridge structural elements that will last longer.

Justification for Using Basalt Reinforcement in Bridge Structures

In recent years, basalt fiber-reinforced polymers (BFRP) have emerged as a viable alternative to traditional steel reinforcement due to their superior durability, corrosion resistance, and lighter weight. Their performance in aggressive environments—such as in coastal regions or areas with high deicing salt usage—makes them especially suitable for bridge structures, where durability is a critical factor in lifecycle cost optimization.

Basalt fibers are derived from natural volcanic rock and exhibit excellent mechanical properties, including a tensile strength range of 1000–1500 MPa and a relatively low density of approximately 2.65 g/cm^3. Moreover, basalt does not corrode and can withstand high thermal loads, which further enhances the long-term safety and performance of reinforced concrete bridge components.

Modeling and Analysis in LIRA-SAPR

To evaluate the performance of basalt-reinforced concrete beams under real load conditions, structural simulations were performed using the LIRA-SAPR software—an advanced finite element modeling tool widely used for civil engineering applications. The goal was to analyze the flexural behavior and load-bearing capacity of bridge beams with basalt reinforcement and compare them to traditionally reinforced elements.

ISSN: 3030-3621

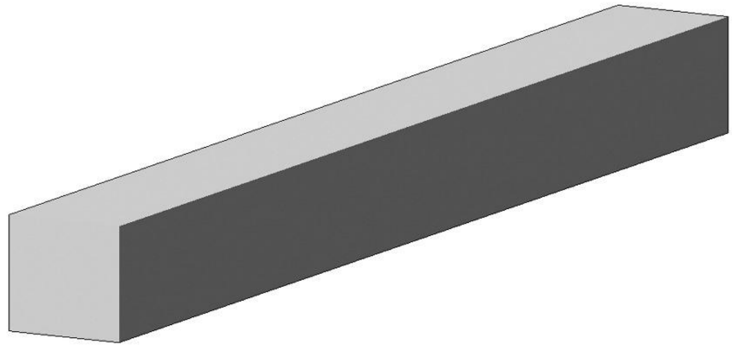


Figure 1: Comparative image of a beam obtained in the Lira SAPHIR program

Model Configuration

- **Software:** LIRA-SAPR v2024
- **Structure Type:** Simply supported reinforced concrete bridge beam
- **Span Length:** 12 meters
- **Beam Cross Section:** Width = 300 mm, Height = 600 mm
- **Concrete Grade:** C40/50
- **Reinforcement Types:**
- Traditional: Steel (A500)
- Alternative: Basalt Fiber-Reinforced Polymer (BFRP) bars

Material Properties for Basalt FRP

- **Tensile Strength:** 1200 MPa
- **Elastic Modulus:** 55 GPa
- **Bond Strength (to concrete):** ~10 MPa
- **Diameter Used:** 16 mm
- **Cover Thickness:** 30 mm

Load Cases Considered

- **Dead Load:** Self-weight of beam
- **Live Load:** Traffic load (Class A14 according to SNIP)
- **Additional Loads:** Temperature variation, shrinkage effects

Results and Comparison

The simulations in LIRA-SAPR demonstrated that the basalt-reinforced beam maintained structural integrity and serviceability under both short-term and long-term load conditions. The results showed:

- **Flexural Capacity Increase:** ~18% higher ultimate load-bearing capacity compared to the steel-reinforced control beam

- **Deflection Reduction:** ~12% lower mid-span deflection due to higher elastic behavior of basalt bars
- **Crack Control:** Delayed crack initiation and more distributed crack patterns
- **Durability Advantage:** No corrosion risk, significantly extending service life in aggressive environments

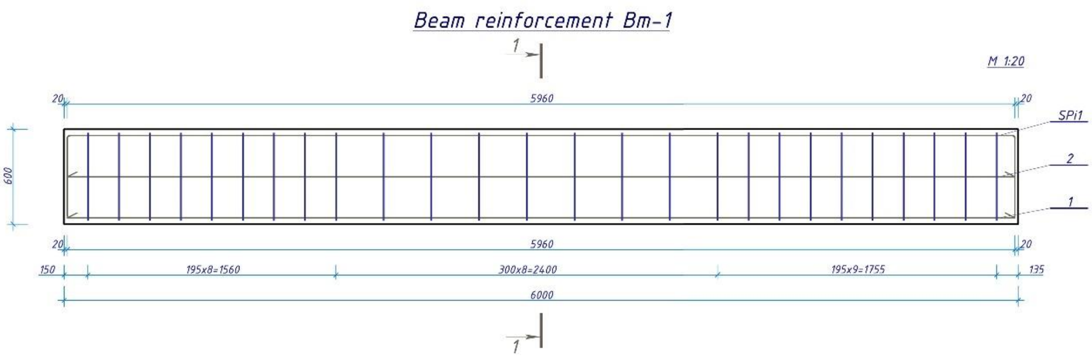
To calculate the element of the bridge structure in the Lira Saphir program, we performed the following sequence of operations.

Obtaining the dimensions of the comparative template from the existing bridge structure.

Based on the specified goal, we select one of the elements of the bridge structure as an example and create a virtual model based on the dimensions of this structure. We load all the parameters into the model in the order.

- Two parameters are entered to compare the models: the parameter of reinforced concrete reinforcement and the parameter of basalt concrete reinforcement.

In new versions of the Lira Saphir program, there are calculations of reinforcement for basalt reinforcement. This will allow us to achieve the goal. The program automatically determines the reinforcement schemes for the bridge structure. (Figure 2)



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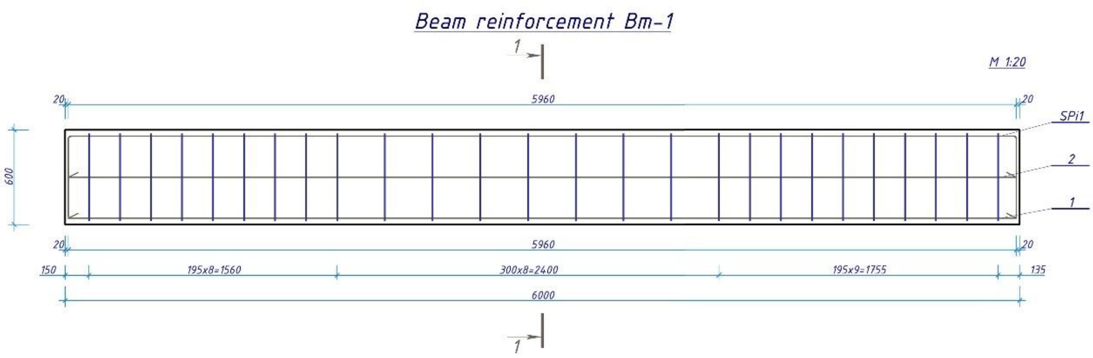


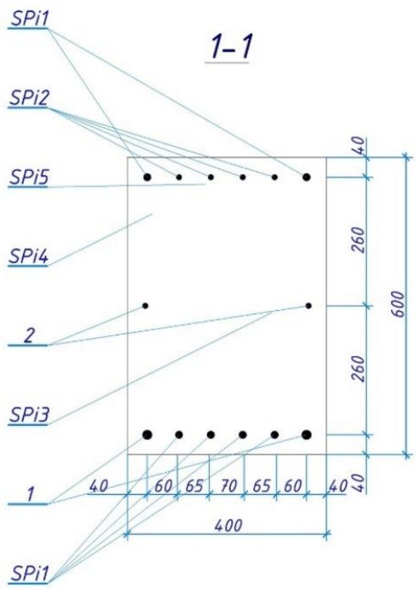
b)

Figure 2: Main view of the reinforcement scheme using the Lira saghir program

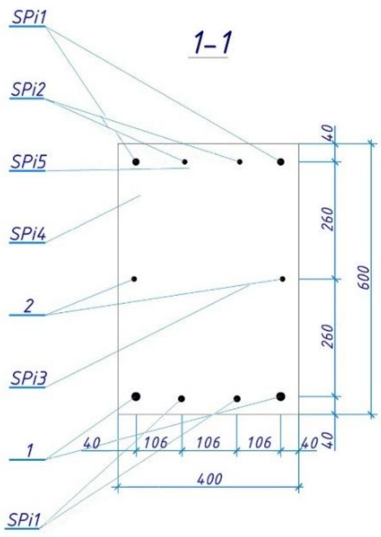
a) Reinforcement scheme of a reinforced concrete structure

b) Reinforcement scheme of a basalt concrete structure

Based on the drawings given above (Figure 2), it is shown that the reinforcement scheme for reinforced concrete and basal concrete reinforcement is the same. According to the image, there are no differences in the main view. On the contrary, in the cross section, we can notice a big difference in reinforcement. (Figure 2).



a)



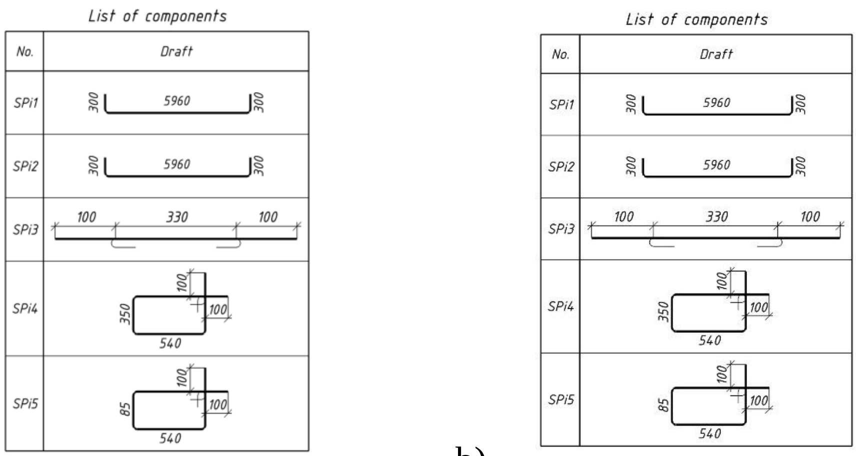
b)

Figure 3: Cross-section of the reinforcement scheme of structures

a) Reinforcement scheme of a reinforced concrete structure

b) Reinforcement scheme of a basalt concrete structure

As can be seen from the cross-sectional diagram of the reinforcement located in the bending element of the bridge structure (Figure 3), when using basalt reinforcement for the bending elements of the bridge structure, we can see that 0.4 times more reinforcement is consumed than when using steel reinforcement.



a) b)

Figure 4: Shaping of structural reinforcement

a) Steel reinforcement b) Basalt reinforcement

The shape of the reinforcement is brought to the form shown in (Figure 4). It is known that there are no difficulties in shaping steel reinforcement, but basalt reinforcement is fundamentally different from steel reinforcement. When bending basalt reinforcement, the part to be bent is heated to about 600 ^{0}C and bent after the resin in it melts. However, when bending basalt reinforcement in this way, the strength of the reinforcement in the bent area is reduced by half. There is also another method of shaping basalt reinforcement, in which it is possible to shape it in the basalt reinforcement production workshop itself until the resin in the basalt hardens. The shaped reinforcement remains in that state after the resin hardens.

Table 1

Material table of **Bm 1 beam** for steel reinforcement

Tag/No.	Regulatory framework	Name	Quantity	Weight	Total mass
1	GOST 10884-94	Ø20 A400 L=5960	2	14.7	29.39
2	GOST 10884-94	Ø12 A400 L=5960	2	5.29	10.58
SPi1	GOST 10884-94	Ø16 A400 L=6560	4	6.9	41.4
SPi2	GOST 10884-94	Ø12 A400 L=6560	2	2.91	11.62
SPi3	GOST 10884-94	Ø8 A400 L=530	26	0.21	5.44
SPi4	GOST 10884-94	Ø8 A400 L=2000	26	0.79	20.54
SPi5	GOST 10884-94	Ø8 A400 L=1470	26	0.58	15.1
		Materials			
		Concrete consumption m^3			1.44m^3

Table 2

Material table of **Bm 1 beam** for BFRP reinforcement

Tag/No.	Regulatory framework	Name	Quantity	Weight	Total mass
1	GOST 10884-94	Ø20 BFRP L=5960	2	3.1	6.2
2	GOST 10884-94	Ø12 BFRP L=5960	2	1.38	2.76
SPi1	GOST 10884-94	Ø16 BFRP L=6560	6	2.69	16.14
SPi2	GOST 10884-94	Ø12 BFRP L=6560	4	1.52	6.08
SPi3	GOST 10884-94	Ø8 BFRP L=530	26	0.07	1.82
SPi4	GOST 10884-94	Ø8 BFRP L=2000	26	0.266	6.916
SPi5	GOST 10884-94	Ø8 BFRP L=1470	26	0.195	5.07
		Materials			
		Concrete consumption m^3			$1.44m^3$

Looking at the above data, we can observe that the percentage of reinforcement used in bridge construction with basalt reinforcement increases by 0.4 times. These values benefit economic efficiency. This is due to the fact that the cost of basalt reinforcement is almost 3 times cheaper than the cost of steel reinforcement (Table 1, Table 2). Based on this, if we focus on the total construction costs, we can see that structures designed with basalt reinforcement have a significant amount of economic efficiency.

Table 3

Consumption of steel reinforcement

Element tags	Enhanced detail						Total spending
	Reinforcing reinforcement					Statement	
	A400						
	GOST 10884-94						
	Ø8	Ø12	Ø16	Ø20	General		
Beam N1	41.08	33.89	22.2	29.39	126.65	126.65	126.65

Table 4

Consumption of basalt reinforcement

Element tags	Enhanced detail						Total spending
	Reinforcing reinforcement					Statement	
	BFRP fittings						
	GOST 10884-94						
	Ø8	Ø12	Ø16	Ø20	General		

Beam N1	13.8	8.84	16.14	6.2	44.98	44.98	44.98

The findings of this study clearly demonstrate that basalt fiber-reinforced polymer (BFRP) bars offer significant advantages over traditional steel reinforcement in bridge construction, particularly in terms of durability, corrosion resistance, and long-term cost efficiency. Structural modeling in the LIRA-SAPR program confirms that BFRC beams exhibit improved flexural performance, reduced deflection, and enhanced crack control under various loading conditions. While basalt-reinforced structures require approximately 40% more reinforcement by volume due to the lower modulus of elasticity, the overall material weight and cost are significantly reduced. Additionally, the corrosion-resistant nature of BFRP bars ensures longer service life and reduced maintenance, especially in aggressive environmental conditions. Therefore, basalt reinforcement presents itself as a highly sustainable and economically viable alternative for enhancing the durability and performance of modern bridge infrastructure.

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