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INVESTIGATION OF INCREASING THE LOAD-BEARING CAPACITY OF REINFORCED CONCRETE COLUMN STRUCTURES OF BUILDINGS BY STRENGTHENING THEM WITH BASALT FIBER MATERIALS.

Foziljon Solijonov
Fergana state technical university, assistant
foziljon.solijonov@fstu.uz (ORCID 0000-0003-4627-7905).
Sevarakhon Nabiyeva
Fergana state technical university, magistr
snabiyeva407@gmail.com

Abstract: This scientific article presents the results of a novel scientific approach to strengthening reinforced concrete compression members using basalt fiber materials. The paper demonstrates methods for strengthening reinforced concrete column elements with basalt fiber materials. Compared to other fiber-reinforced polymer materials, basalt fiber materials are more cost-effective, have a higher tensile strength limit, and exhibit greater durability.

Keywords: basalt fiber materials, physical and chemical properties, reinforced concrete column structure, workability, hardened concrete.

Introduction: The rapid development of modern construction processes worldwide, as well as the strengthening of existing building and structure components and the extension of their service life through the use of advanced composite materials and reinforcement systems, have become issues of particular importance. Problems related to increasing the strength of reinforced concrete column structures mainly arise due to factors such as the design of new structural systems, reconstruction of existing buildings, an increase in loads acting on structures, or changes in the spatial and planning dimensions of buildings [1-4].

When designing buildings and structures, these issues are addressed by using high-strength materials. However, during reconstruction and repair works, they are resolved through various structural solutions, including strengthening with steel or reinforced concrete jackets, external reinforcement of structural elements, or injection with special grouting mixtures. In particular, special attention is currently being paid to the use of modern composite materials for strengthening structural components.

In our republic, significant attention is being paid to the development of the construction industry and the application of innovative modern composite materials in construction in order to reduce the self-weight of structures, conserve metal ore resources, ensure the reliability of building and structural components, and develop new structural solutions. The analysis of the stress–strain state of concrete and reinforced concrete structures strengthened using composite materials, as well as the calculation of the strength and stability of strengthened concrete structures subjected to compression and the development of practical recommendations for their design, are considered among the most relevant tasks.

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The degree of physical deterioration of columns is assessed in accordance with the regulatory document **BCH 53–86(r)** [5]:

"The actual degree of physical deterioration of a reinforced concrete column is determined based on the assessment of defects in individual parts of the column surface and is calculated using a special formula."

$$\Phi_к = \sum_{i=1}^{i=n} \Phi_i \frac{P_i}{P_к},$$

Where:
Φ_k — overall degree of deterioration of the column, %;
Φ_i — degree of deterioration of an individual part (section) of the column, %;
P — area of the column section with the same degree of deterioration, m²;
P_k — total surface area of the column, m²;
n — number of column sections exhibiting different levels of deterioration.

The scope of works for strengthening physically deteriorated structures presented in the regulatory document BCH 53–86(r) approximately reflects their technical condition; however, it does not fully cover modern repair technologies. Nevertheless, the issue of strengthening reinforced concrete structures using composite materials remains highly relevant, and regulatory documents in this field are being developed not only in Uzbekistan but also internationally [6].

A more precise assessment scale for determining the degree of physical deterioration of concrete columns has been developed by the authors based on practical observations and generalizations. On this basis, new repair methods using basalt fiber composite materials have been proposed. Over the past decade, technologies involving the bonding of basalt fiber tapes and fabrics with tensile mechanical strength **R = 1700–4800 MPa**, used as external reinforcement for strengthening structures, have become widely applied (Figure 1) [7]. In addition, the method of monolithization of reinforced concrete structures by injecting cracks has also gained widespread use.

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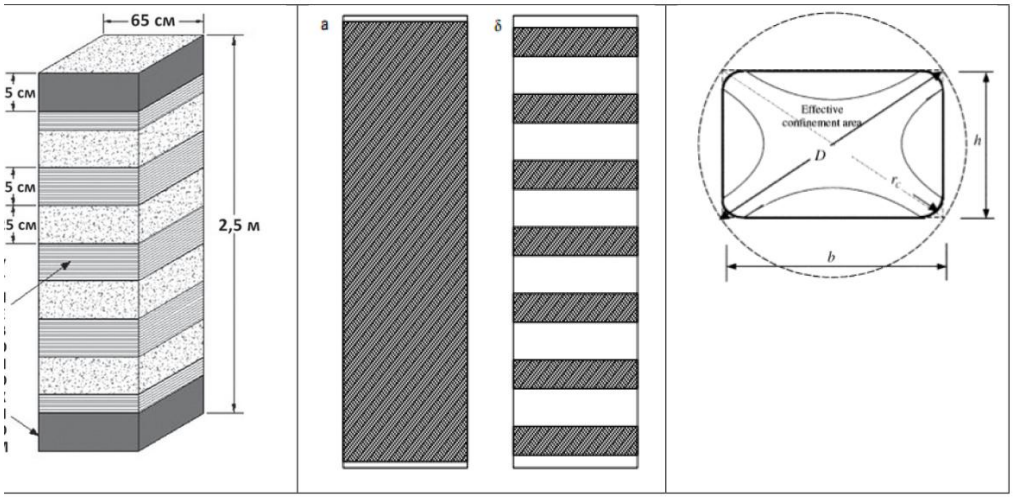

Figure 1. Strengthening of columns using basalt fiber materials [9, 10]

The test results showed that the load-bearing capacity of the columns increased by **57%**. The axial compression deformation of the columns at the ultimate limit state reached **11 mm/m**, which is considered an unacceptable value at the serviceability stage. Therefore, basalt fiber materials are applied to columns operating near the ultimate load level to ensure the required reliability coefficient. For loaded columns, the recommended strengthening coefficient ranges from **1.8 to 2.0** [8].

Before bonding basalt fiber fabrics or strips to the concrete surface of a column using an epoxy adhesive mixture, cracks with a width of 1–2 mm are repaired by injection. This simple technological process includes the following steps:

1. Opening and cleaning the cracks;
2. Drilling holes for injection packers at an angle of 30–45°;
3. Cleaning the holes with compressed air;
4. Installing the injection equipment;
5. Injecting the polymer–cement mixture into the holes;
6. Removing the packers;
7. Sealing the holes with the polymer–cement mixture;
8. Repairing surface cavities and minor damages on the concrete with the polymer–cement mixture.

The installation of the external reinforcement system is carried out under conditions of air temperature between +5 °C and +45 °C, with relative humidity not exceeding 80%. The temperature of the structure should be at least 3 °C above the dew point, and the moisture content of the concrete in the reinforced zone must not exceed 4% [9].

Strengthening reinforced concrete structures with composite materials using external reinforcement involves the following main stages:

- Restoring the integrity and geometric shape of the structure to be strengthened (and performing anti-corrosion treatment if necessary);

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- Preparing the surfaces where the reinforcing elements will be applied;
- Determining the external reinforcement elements according to the design and drawing the layout scheme;
- Preparing the reinforcing elements (strips, fabrics, laminates, meshes, or anchor-carrying cords) for installation;
- Bonding the reinforcing elements;
- Applying a protective coating [9].

In modern construction practice, traditional methods for strengthening reinforced concrete columns are still used. These methods are intended for structures with more than 25% physical deterioration, and unified standards have been developed reflecting the required technical and labor resources and costs for such works. Traditional strengthening technologies include:

1. Installation of a steel shell assembled by electric welding from steel profiles (angles, steel strips) (Figure 2);
2. Construction of a monolithic reinforced concrete shell;
3. Shotcrete application on a steel shell prepared from construction reinforcement.

If the thickness of the reinforced concrete shell does not exceed 4 cm, the shotcrete method (Figure 3) can be used.

Figure 2. Strengthening a column using a steel shell.

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Figure 3. Technological process of strengthening a reinforced concrete column with a shell made of reinforced shotcrete.

According to expert evaluations, the external reinforcement of columns with up to 25% deterioration using basalt fiber fabrics is considered the most effective technology.

The least effective method is the injection technology, while the steel shell performs better than a reinforced concrete shell, but still yields inferior results compared to basalt fiber fabric. However, due to insufficient data on the long-term performance and durability of basalt fiber materials, the authors do not recommend strengthening reinforced concrete columns with more than 25% deterioration using basalt fabrics.

It is recommended to apply the epoxy adhesive composition to the prepared concrete surface at temperatures not lower than +15 °C [10].

Foreign studies: International research on strengthening columns using basalt fiber materials has focused on the automated wrapping process of the strips.

Conclusions: In conclusion, the main objective of this study was to determine the feasibility of using externally bonded basalt fiber materials for strengthening reinforced concrete columns.

The results indicated that the application of basalt fiber materials on reinforced concrete columns improves the following characteristics:

- Flexural strength;
- Modulus of elasticity;
- Compressive strength;
- Tensile strength;
- Durability under compression and fracture.

Since basalt fiber materials are more cost-effective compared to other widely used fibers such as carbon and polypropylene, they can be efficiently employed to enhance the performance of reinforced concrete column structures.

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