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# STRENGTHENING REINFORCED CONCRETE STRUCTURES WITH COMPOSITE MATERIALS

**Pustovoitova Oksana Mykhailivna**, PhD, Associate Professor Department of Building Constructions, O.M. Beketov National University of Urban Economy, e-mail: oksana_pustov@ukr.net, ORCID ID 0009-0003-4774-6686
**Atynian Armen Ovikovich**, PhD, Associate Professor Department of computer graphics, Kharkov National Automobile and Highway University, Ukraine, e-mail: Armen.Atynyan@kname.edu.ua ORCID ID 0000-0002-0329-2702
**Gvozdiuk Oleksandr Anatoliyovych**, postgraduate, Department of Building Constructions, O.M. Beketov National University of Urban Economy, e-mail: gvozduksasha@gmail.com, ORCID ID 0009-0000-7856-9094

Enhancing the durability and operational reliability of buildings and structures is a priority task in modern construction. During their service life, load-bearing elements are subjected to factors that lead to a reduction in their load-bearing capacity, the development of defects, and, in some cases, a pre-emergency condition. Buildings slated for reconstruction or exhibiting signs of damage undergo technical inspection. Based on the inspection results, a technical report is prepared with recommendations for the restoration or strengthening of the structures. In cases where defect elimination is not possible through routine repairs, design solutions for strengthening the load-bearing elements are developed [1].

Work on strengthening historically valuable or technically complex structures, whose demolition is economically unfeasible or technically impossible, holds particular relevance. Alongside traditional strengthening methods using steel elements, technologies employing composite materials, specifically external reinforcement systems, have become widespread.

Modern composite materials, manufactured on a glass fiber basis, are characterized by high strength, linear-elastic behavior, low weight, and corrosion resistance. These properties ensure their effectiveness in the repair and strengthening of structures made of reinforced concrete, metal, wood, and other materials. External reinforcement elements are applied in the form of strips or sheets, which are bonded to the structure's surface using polymeric or polymer-cement adhesives. In service, these systems effectively absorb additional deformations, facilitating the redistribution of internal forces and enhancing the structure's load capacity [2].

The primary advantages of external GFRP reinforcement include the low self-weight of the strengthening elements, the possibility of installation without heavy lifting equipment, effectiveness in confined or complex construction conditions, corrosion resistance, suitability for use in aggressive environments, a minimal increase in the structure's cross-section dimensions, and reduced construction time. However, the application of such systems requires consideration of the temperature limitations of the polymer matrix, proper preparation of the concrete substrate, and the involvement of qualified personnel.

External reinforcement systems are used to strengthen beams, floor slabs, columns, foundations, truss elements, and other structures, ensuring an increase in their load-bearing capacity and extending their service life. The use of glass-fiber materials allows for a reduction in labor intensity, shorter reconstruction timelines, and a significant increase in the efficiency of restoring buildings and structures that are in an unsatisfactory technical condition.

The application of glass fiber for strengthening reinforced concrete structures is driven by its high strength and linear-elastic properties, which ensure the material's effective performance within external reinforcement systems. Glass fiber materials are manufactured in the form of fabrics made from fibers obtained through the thermal treatment of raw materials in an inert atmosphere. In strengthening practice, they are applied as strips or sheets, functioning as additional reinforcement.

The attachment of external reinforcement elements to reinforced concrete structures is carried out using epoxy, epoxy-polyurethane, or polymer-cement adhesives, which ensure a reliable bond with the substrate. During service, these elements actively engage in absorbing the structure's deformations, accompanied by an increase in stresses within the strengthening layer and a rise in the load-bearing capacity of the element.

The main advantages of GFRP-based external reinforcement systems include: the low self-weight of the strengthening elements compared to steel solutions; the absence of a need for lifting equipment during installation; the feasibility of working in confined or enclosed spaces; effectiveness at sites with difficult transport access; suitability for operation in aggressive environments, particularly under the action of liquid aggressive media and the possibility of performing work underwater; the corrosion resistance and electrical non-conductivity of the material; reduced construction time; and the negligible thickness of the strengthening layer, which does not reduce the floor-to-floor height or alter the structure's geometric parameters.

Despite their significant advantages, GFRP-based external reinforcement systems have several limitations. Notably, the maximum service temperature of such systems is generally within the range of approximately 60–150 °C, necessitating the provision of thermal and fire protection. Elevated requirements are imposed on the strength and quality of the concrete surface preparation, and the execution of work requires the involvement of qualified personnel with specialized training.

The main requirements for the application of external reinforcement systems include: preventing the exceedance of the glass transition temperature of the polymer matrix and adhesive; ensuring adequate concrete strength (typically, a minimum compressive strength of 15 MPa, except in cases of jacketing for compression members where mechanical interlock is decisive); and a rational strengthening level, generally within 10–60% of the original load-bearing capacity. These systems are used for the longitudinal and transverse reinforcement of linear members, the jacketing of columns, supports, and corbels, as well as for strengthening slabs, truss elements, and other structures.

It should be noted that the application of composite systems does not halt ongoing corrosion processes in the steel reinforcement. Therefore, prior to strengthening, it is necessary to perform anti-corrosion treatment, restore the concrete cover, and ensure proper adhesion of the repair materials to the existing substrate.

## Conclusions

External reinforcement with glass fiber strips is widely applied for the repair and restoration of reinforced concrete structures damaged due to reinforcement corrosion or the action of aggressive environments. Compared to traditional methods that require significant labor input and the installation of additional formwork, composite technology enables a reduction in construction time (within 1–3 weeks, depending on the scope), a multiple increase in the load-bearing capacity of elements, and an extension of the inter-repair service period. The use of glass fiber opens up possibilities for the effective restoration and service life extension of aging and damaged buildings.

## References

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