

Strengthening of tensile zone of the reinforced concrete beams with composite fabrics

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Abstract. A fabric, tapes, that are glued to the outer tensile surface, which are considered as the external composite reinforcement with tensile steel reinforcement, are currently used to strengthen reinforced concrete beams. The results of the experimental studies presented in this article have shown the possibilities of effective application of technical polyamide (nylon) fabric produced by «Khimvolokno Plant» JSC «Grodno Azot», and glass fabrics, produced by JSC «Polotsk-Steklovolokno» for strengthening the reinforced concrete beams. Experimental studies have shown that the external reinforcing of the tensile zone with technical polyamide (nylon) fabric and fiberglass changes the beam failure mode, increases the bearing capacity of reinforced concrete beams in comparison with beams without strengthening by 16% – 38%, depending on the material and the method of strengthening.

1 Introduction

Reinforced concrete structures occupy a leading place in the construction industry, and with the increase in the volume of construction, the volume of work associated with the repair, restoration and strengthening of structures also increases. The analysis of strengthening of reinforced concrete structures has shown that the traditional methods of strengthening associated with an increase in the cross-section dimensions, the arrangement of external elements, changes in structural schemes, etc. have exhausted themselves, since their further development will bring insignificant savings in materials. The results of modern research have shown [1–13] that it is possible to achieve greater savings in materials, reduce costs in the production of reinforcement work by using composite materials.

Currently, there are many different composite materials (Table 1), as well as ways to strengthen structures.

External reinforcement of beam structures is carried out by gluing reinforcing materials to the lower stretched surface with the direction of reinforcing fibers along the axis of the structure. Glued fabrics, tapes are external composite reinforcement, which, together with metal reinforcement, perceive stretched forces [15].

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Table 1. Typical properties of composite materials fibers [14].

Type of fiber	Tensile strength, MPa	Modulus of elasticity, GPA	Relative elongation strain, %	Density, t/m ³
Carbon Fiber	4300 – 5100	230 – 280	1,6 – 1,73	1,75
Carbon Fiber	2740 – 5490	294 – 329	0,7 – 1,9	1,78 – 1,81
Carbon Fiber	2600 – 4020	390 – 760	0,4 – 0,8	1,85 – 1,90
Aramid fibers	3200 – 3600	124 – 130	2,4	1,44
Fiberglass	2400 – 3500	70 – 85	3,5 – 4,7	2,6

The advantages of using external reinforcement that is made of composite materials are:

- low specific gravity of composite materials in relation to reinforced concrete, which simplifies installation,
- joint work of composite material (external reinforcement) and reinforced structure, which is ensured by a reliable adhesive connection;
- reinforcement elements, based on composite materials, resistant to corrosion and aggressive environments, which leads to increased durability and protection of the glued face from corrosion;
- the ability to work in cramped conditions;
- work can be carried out as soon as possible.

The most common for the restoration of reinforced concrete structures is currently a system of external reinforcement with carbon tapes. As a result of experimental studies [16 – 20], it was found that beams reinforced with carbon canvas work more elastically and have increased bearing capacity and rigidity. However, the introduction of this material is limited by the high cost.

2 Experimental study

The experimental studies of reinforced concrete beams reinforced from destruction by normal cross-section were carried out to determine the most effective method and material of strengthening reinforced concrete structures.

Two series of experimental beams with dimensions of 60×120×1000 mm were manufactured and tested to study the load-bearing capacity of bent elements strengthened with composite materials: beams of series I (B2, B3) were strengthened with fiberglass produced by JSC «Polotsk-Steklovolokno», beams of series II (B4, B5) were strengthened with technical polyamide (nylon) fabric produced by «Khimvolokno Plant» JSC «Grodno Azot». In each series, the beams had a different strengthening option: beams B2, B4 were reinforced with composite fabrics only on the lower surface, B3, B5 – with a U-shaped cage in the stretched zone.

A beam without reinforcement was tested (B1) to determine the effectiveness of reinforcement. The beam was reinforced with a welded frame made by spot welding. Longitudinal stretched rebar – metal rebar Ø10 of class S500, compressed zone rebar – Ø6 of class S240. The transverse reinforcement Ø10 of class S240 is installed in increments of 50 mm.

The beams were manufactured at the efficiency plant of JSC "Grodnozhilstroy" from concrete of class C25/30.

The tests were carried out with the application of concentrated forces at a distance of 1/3 of the beam length from the supports (Fig. 1), since a constant bending moment acts in the zone between the concentrated forces, and there is no transverse force. In this zone, only normal stresses act, which makes it possible to assess the bearing capacity of the section without the influence of other factors. Experimental studies of the beams were carried out on an IP6084-1000-0 testing machine.



Fig. 1. Test bench for experimental beams.

Analysis of the destruction of the experimental beams showed that the destruction of the unreinforced beam occurred along the normal section in the clean zone as a result of plastic deformations in the tensile zone of the reinforcement at a load of 19.46 kN. The destruction of the reinforced beam B2 occurred along an inclined section at a load of 24.69 kN, beams B3, B4 and B5 along normal sections due to crushing of concrete in the compressed zone, at a load of 26.2 kN; 22.57kN; 26.91 kN, respectively (Fig. 2).



Fig. 2. The nature of the destruction of experimental reinforced beams.

It has been experimentally established that external strengthening changes the nature of the destruction and confirms the effectiveness of these amplification options regardless of the amplification option.

The analysis of the bearing capacity of the experimental beams showed (Figure 3):

- the maximum value of the breaking load was shown by beams, that were strengthened with a U-shaped cage in the tensioned zone (B3, B5); the increase in the breaking load was 34.63% when using fiberglass for reinforcement, and - 38% when using technical polyamide (nylon) fabric;
- an increase in the breaking load of beams, that were strengthened only along the lower edge, was 26% when using glass fabric reinforcement, and - 15% when using technical fabric reinforcement;
- beams with fiberglass reinforcement had a bearing capacity of 26.9% - 34.63% more than beams B1;
- beams with technical fabric reinforcement had a bearing capacity of 16% - 38% more than beams B1.

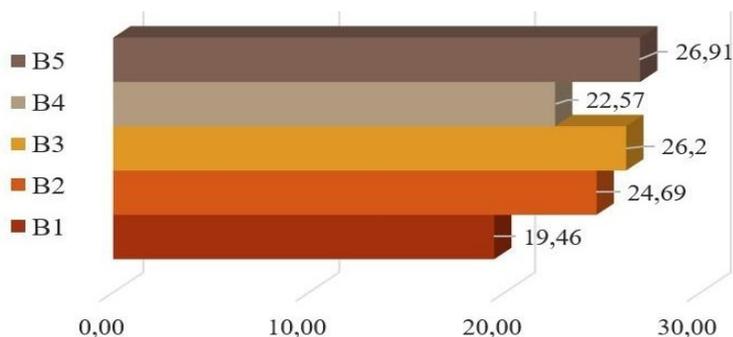


Fig. 3. – Bearing capacity of experimental beams

3 Conclusion

It is made a calculating estimate the conditions for ensuring the uniform strength of rupture and braid coils of construction composite reinforcement bar for shear and crushing. Theoretically substantiated the assumption of a relatively low loading capacity of the braid coils in comparison with the loading capacity of the reinforcement bar. The results obtained can be used by manufacturers and consumers of construction composite reinforcement, also in the educational process at the training of engineering personnel for the construction profile.

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