Research on the Influence of the Percentage of Longitudinal and Fiber Reinforcement on the Strength of Normal Sections of Rubber Concrete Beams of a T-Section

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Abstract. This article presents the results of testing the strength of samples of rubcon and fiber rubcon beams of a T-section, with a different percentage of longitudinal reinforcement. Rubber concrete (or abbreviated as rubcon) is a highly effective composite polymer concrete based on liquid rubber, which has favorable physical and mechanical characteristics, as well as almost universal chemical resistance to corrosive media. Bars of class A500C were used as longitudinal reinforcement; as transverse- Bp500, with a diameter of 5 mm and a step of 50 mm. Fiber reinforcement is represented by steel fibers with a diameter of 0.3 mm and a length of 30 mm (that is, a ratio of diameter to fiber length of 1/100) arranged randomly throughout the entire volume of the experimental beams. The section of the beams is assigned with the requirements of CR 63.13330.2012 "Concrete and reinforced concrete structures": length - 1400 mm; web height - 95 mm; web width - 60 mm; flange height - 25 mm; flange width - 240 mm; the number and diameter of the longitudinal rebars - 0; 1Ø8; 1Ø10; 2Ø10; 2 Ø12 mm; which corresponds to the percentage of longitudinal reinforcement - 0; 0.80; 1.25;2.50; 3.60%. The technique of experimental studies of bending elements of mixed reinforcement is described. The results of testing beams for pure bending are presented. It is established that with an increase in the percentage of longitudinal reinforcement, the value of the destructive bending moment increases in a linear relationship. When adding fiber reinforcement, an increase in the values of the destructive bending moment is observed up to 10%.

1. Introduction

Ensuring the safety of buildings and structures during a given period of operation, increasing the overhaul period and reliability of structures are one of the main ways to improve the efficiency of capital investments in market conditions. Elements of structures often work in difficult conditions under the influence of aggressive media of various nature, while the use of traditional materials (reinforced concrete and steel) without additional protective measures is ineffective. A promising way to solve this problem is the implementation of such structures from effective composite materials, for example, polymer concrete - materials that use polymers of various nature as a binder.
Composite material - rubber concrete (rubcon), obtained on the basis of liquid rubbers, has a high, almost universal chemical resistance. Chemical resistance coefficients are given in table 1.

Analysis of previous studies shows that, on the basis of rubber concretes, it is possible to create highly effective reinforced structures of different cross sections [1-6, 8-17].

### Table 1. Chemical resistance coefficients of rubcon.

| Type of aggressive medium | Chemical resistance coefficient after 1 year of exposure | Projected after 10 years |
|--------------------------|--------------------------------------------------------|-------------------------|
| 20% sulphuric acid solution | 0.95 | 0.95 |
| 3% solution of nitric acid | 0.8 | 0.7 |
| 10% citric acid solution | 0.9 | 0.8 |
| 20% sodium hydroxide solution | 0.95 | 0.95 |
| 10% potassium hydroxide solution | 0.8 | 0.65 |
| Saturated sodium chloride solution | 0.9 | 0.8 |
| Diesel fuel | 0.95 | 0.95 |
| Water | 1 | 0.99 |

2. Experimental part

The samples were tested according to the single-span beam design scheme. They were loaded with two concentrated forces located in the thirds of the calculated span of 120 cm. The loading scheme and the section of the beams are shown in fig. 1. Deformations of the compressed and tensile edge in the zone of pure bending and working reinforcement were measured using resistance strain gauges with a base of 20 mm.

![Figure 1. Loading scheme of beam cross-section.](image)

The tests were conducted at the Center of collective use (CCU) named after Professor Yu.M. Borisov of VSTU. The following devices were used: the Universal Floor Hydraulic Test System Model 600KN INSTRON (USA), a complex of equipment for monitoring stress-strain and technical condition of structures and their elements (Germany). A general view of the beam before and after the experiment is presented in fig. 2.

![Figure 2. General view of the beam before (a) and after the experiment (b).](image)
It is worth noting that during the testing of a BRT beam (beam, rubber concrete of a T-section), without longitudinal bar reinforcement, the destruction of the beam came with the appearance of the first crack, while in the BFRT beam (beam, fiber rubber concrete of a T-section), the destructive moment occurred after the formation of a crack, this says that fiber reinforcement is included in the work and it can be used (in certain cases) as a replacement for the longitudinal.

In beams with longitudinal bar reinforcement, the destructive bending moment was taken at which the stresses in the reinforcement reached the limit of ductility. With further loading, the beams are deformed intensively with a practically constant load value. Experimental data of sample beams are presented in table 2.

Table 2. Experimented strength of normal sections of rubcon and fiber rubcon beams.

| Beam grade | Reinforcement , % | $M_u$, kN · m | $R_{uk}$, MPa | $R_{kt}$, MPa |
|------------|-------------------|----------------|----------------|---------------|
| BRT-0      | 0,00              | 2,03           | 80,00          | 9,00          |
| BRT -10    | 1,25              | 5,82           | 79,00          | 9.10          |
| BRT -2x10  | 2,50              | 8,85           | 79.10          | 9.50          |
| BRT -2x12  | 3,60              | 11,52          | 82.00          | 10.20         |
| BFRT-0     | 0,00              | 2,24           | 85,00          | 13.00         |
| BFRT -8    | 0,80              | 4,60           | 81,00          | 11.12         |
| BFRT -2x10 | 2,50              | 8,90           | 83.20          | 11.00         |
| BFRT -2x12 | 3,60              | 13,47          | 87.60          | 13.00         |

Note: BRT-0 cipher decryption: B - type of element, in our case a beam; R - material of which the bending element is made (fiber rubcon, rubcon); T – type of cross-section, in our case T-section; 0 - the number indicates the diameter of the longitudinal bars.

It has been established that the percentage of longitudinal reinforcement has a significant influence on the strength of the normal sections of the rubcon and fiber rubcon beams, fig. 2. It is established that the strength increases according to a linear law. With an increase in the percentage of reinforcement from 1.25 to 3.60%, $M_u$ increases by 2 times for rubcon beams and 2.2 times for fiber rubcon beams. It was also found that the strength of normal sections of fiber rubcon beams is higher than similar rubcon ones in the whole range of variation of the reinforcement percentage, so for $\mu = 1.25%$ $M_u$ in BFRT is higher than $M_u$ in BRT by 1.03 times, at $\mu = 3.60%$ $M_u$ in BFRT is higher than $M_u$ in BRT by 1.17 times.

Figure 2. The relationship between the bending moment ($M_u$) and the percentage of longitudinal reinforcement ($\mu$).
3. Analysis of test results

The obtained data on the deformations that occur in the flange of the compressed zone of fig. 3, in BFRT beams, due to higher strength, the strain value is greater than that of BRT beams; the strain distribution in the flange is close to linear, with some curvature when approaching the edge of the flange.

In BRT and BFRT beams without longitudinal bar reinforcement, the maximum relative deformations near the wall are $302*10^{-6}$ and $321*10^{-6}$ m/m, respectively, in the flange most compressed fiber from the wall, the value drops to $236*10^{-6}$ and $290*10^{-6}$ m/m.

In beams BRT-2X12 and BFRT-2X12 near the walls, we have $1671*10^{-6}$ and $1857*10^{-6}$ m/m, in the flange most compressed fiber from the wall, we have $1363*10^{-6}$ and $1515*10^{-6}$ m/m.

For further consideration of the nature of the distribution of deformations in the compressed zone across the flange width, sample beams without bar reinforcement and beams reinforced with $\mu = 1.25$, 3.60% are considered.

![Graph](image)

Figure 3. Distribution of deformations (\(\varepsilon\)) across the width of the flanges of the experimented BFRT (a) and BRT (b) beams at the loading stage of 90% of the breaking moment (\(M_u\)), the center of the width of the flange begins with the coordinate “0” (axis of the beam section).

In all beams, a decrease in the strain value from the axis of the beam section to the outermost flange fiber is observed. In BRT-0, this drop is 30%, in BFRT-0 - 40%, in beams BRT- 2X10 and BFRT-2X10 - 15%, in beams BRT- 2X12 and BFRT- 2X12 - 18%. This suggests that the flange, when turned on, remains underloaded, due to the deplanation (curvature) of the section between the flange and the beam web (deformations of the edges of the flange lag behind the deformations of the middle of the web). Since the degree of participation of the flange in the work largely determines the bearing capacity of T-beams when working on flexure, the question of experimental studies of increasing the width of the flange, as well as reducing the thickness of the flange until a uniform distribution of deformations is formed in the reinforced rubber concrete and reinforced fiber rubber concrete beams remains open and deserves further consideration.
4. Conclusion
It has been experimentally proven that the value of deformations across the width of the flange in reinforced rubber concrete and reinforced fiber rubber concrete beams does not remain constant; acquiring maximum values above the web, they fall along the width of the flange (as the distance from the web increases).

An analysis of experimental data shows that the pattern of strain distribution in reinforced rubber concrete and reinforced fiber rubber concrete of bending elements with longitudinal reinforcement has a similar pattern of strain distribution.

It has been established that a flange in beams without longitudinal bar reinforcement of a T-section with fiber reinforcement is more intensively involved in the work than in beams without disperse reinforcement.

An analysis of the experimental data showed that with the addition of fiber filaments, the values of the deformations occurring near the web and at the extreme points of the compressed flange zone increase.

It is established that the relationship between the destructive bending moment and the percentage of longitudinal reinforcement is linear.

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