Comparative analysis of the durability of normal sections reinforced rubber concrete with fiber and reinforced concrete bending elements

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Abstract. To solve problems, associated with the research of the resistance of the normal section of reinforced rubber concrete with fiber bending elements resistance to the action of external loads were produced and tested for cross-bending samples-beams of size 60×120×1400 mm. The percentage of longitudinal reinforcement is set as an optimization parameter in the experiment, has the greatest impact on the resistance of normal sections of the bending elements. The response function was the strength of normal sections. For comparison, was calculated of durability of normal sections for concrete B25 according to the applicable norms.

1. Introduction

It should be noted that in General, the work of building structures made of composites for special purposes, similar to reinforced concrete. However, the nature of such structures has a specificity associated with the need (in some cases) partial account of the tensile zone in the calculation of durability; with features of physical and mechanical properties of rubber concrete – first of all, in terms of taking into account the increased deformability of composites and, as well as increased durability and a higher level of cracking. The above causes the use of design prerequisites for reinforced concrete elements in relation to composite building structures, with the necessary refinement of the design dependencies.

Rubber concrete characteristic favorable deformation-strength characteristics, good insulating and damping properties, high adhesion to metal surfaces, etc., However, the main feature distinguishing rubcon is it large water and chemical resistance. For example, the coefficient of chemical resistance in water is 1, and in solutions of the most common acids, alkalis or salts is close to this value. Studies show that the size of rubcon adhesion, for example, to the metal surface is 12 ... 13 MPa (0.8...0.9 rubcon tensile strength), for comparison, a similar figure in cement 0.5...0.7 MPa. High chemical resistance and adhesion, together with the value of the rubcon thermal expansion coefficient close to steel, ensure the creation and effective operation of reinforced rubber fiber concrete structures at all stages of their exploitation. Insertion to the composition of the Canton of steel fiber leads to the fact that the constructions of armorubcon with fiber have even more advanced performance and can be effectively used in various fields of industrial production. In the process studies of the properties of
rubcon and building structures on its basis, which is engaged: Yu. M. Borisov[1,2,3,4], Potapov Yu. B [5,6] and other researchers [8-12], was proved the effectiveness of this material and designs based on it. The composition of fiberrubcon and its properties are presented in table. 1.2.

| The name of components | Contents of components, wt. (%) |
|------------------------|-------------------------------|
| Rubber SKDN-N          | 8,2                           |
| Sulphur technical      | 4,0                           |
| Thiuram-D              | 0,4                           |
| Zinc oxide             | 1,2                           |
| Calcium oxide          | 0,4                           |
| Fly ash                | 7,8                           |
| Sand                   | 24,2                          |
| Crushed stone          | 49,8                          |
| Fibers from metal-cord waste (fiber) | 4,0 |

**Table 2.** Physico-mechanical properties of fibrorubcon.

| Properties              | Value for fiber rubber concrete |
|-------------------------|----------------------------------|
| Compressive strength, (MPa) | 70…100                           |
| Tensile strength, (MPa)   | 10…20                            |
| The modulus of elasticity, (MPa) | 8000…20000                   |
| Poisson ratio            | 0,2…0,3                         |
| Shrinkage, (mm/m)        | –                               |

This paper is devoted to the comparison of the strength of normal sections bending elements rectangular cross section produced of reinforced fiber rubber concrete with analogical reinforced concrete beams exposed to cross-bending with different percentages of longitudinal reinforcement.

2. **Experimental researches of armofiberrubcon and comparison of reinforced concrete**

To achieve this goal have been made and tested armofiberrubcon beams with the same variable parameter, as the percentage of longitudinal reinforcement. To compare the work of the studied structures with reinforced concrete, their calculation was carried out by [14]. The parameters of the experimental and theoretically calculated armofiberrubcon and reinforced concrete beams add in table 3.

**Table 3.** Parameters of experimental and theoretically calculated beams.

| The length of the beam, (mm) | 1400          |
| Beam width, (mm)             | 60            |
| Beam height, (mm)            | 120           |
| Number and diameter of longitudinal reinforcement bars, (mm) | 0; 1Ø8; 1Ø10; 1Ø12; 2Ø10; 2Ø12; |
| The percentage of longitudinal reinforcement, (%) | 0; 0,8; 1,25; 1,8;2,5; 3,6 |

The load scheme of the bending elements is shown in figure 1.
Figure 1. The load scheme and the section of the bending elements

The beam installed in the press is shown in figure 2

Figure 2. Test beam in the press

The results of experimental studies armofiberrubcon bending elements are summarized in table 4

| Beam code  | The diameter of the rods | Percentage of reinforcement | M_{ult} (kN*m) |
|------------|--------------------------|-----------------------------|----------------|
| BRF - 0(0) | 0                        | 0                           | 2,616          |
| BRF - 0,8 (8) | 8                      | 0,8                         | 3,78           |
| BRF - 1,25 (10) | 10                     | 1,25                        | 5,588          |
| BRF - 1,8 (12) | 12                     | 1,8                         | 6,772          |
| BRF - 2,5 (2x10) | 2x10                   | 2,5                         | 8,774          |
| BRF - 3,6 (2x12) | 2x12                   | 3,6                         | 11,282         |

The theoretical calculation of the ultimate destructive moment for reinforced concrete elements was carried out according to [13] p.8.1 according to the following formulas:

\[ M_{ult} = R_b \cdot b \cdot x \cdot (h_0 - 0.5x), \]  \hspace{1cm} (1)

where

\[ x = R_s \cdot A_s / R_b \cdot b \]  \hspace{1cm} (2)

The results of calculations of reinforced concrete beams are summarized in table 5
Table 5. The results of calculation of reinforced concrete beams and comparison of destructive moments.

| Beam code | The diameter of the rods | Percentage of reinforcement | \( M_d \), (kN*m) | \( M_{ult} \), (kN*m) | \( M_d / M_{ult} \) |
|------------|--------------------------|-----------------------------|-------------------|---------------------|-----------------|
| BR - 0.8 (8) | 8                        | 0.8                         | 3.78              | 1.08                | 3.5             |
| BR - 1.25 (10) | 10                       | 1.25                        | 5.588             | 1.63                | 3.44            |
| BR - 1.8 (12) | 12                       | 1.8                         | 6.772             | 2.24                | 3.03            |
| BR - 2.5 (2x10) | 2x10                     | 2.5                         | 8.774             | 2.92                | 3.01            |
| BR - 3.6 (2x12) | 2x12                     | 3.6                         | 11.282            | 3.77                | 2.99            |

As a result of the calculation of the first group of limit States, according to SP 63.13330.2012, reinforced concrete beams with the same geometric characteristics and the percentage of reinforcement made of concrete B25, received that the value of the breaking moment will be less than that of the experimental samples of fiberrubcon 3 times. For comparison of the destructive bending moment on a figure 3 shows the graphs of dependence of the destructive bending moment on the percentage of reinforcement for structures made of fiber-rubber concrete and concrete B25 with longitudinal reinforcement.

![Figure 3](image)

**Figure 3.** Graphs of the dependence of the destructive bending moment on the percentage of longitudinal reinforcement for armofiberrubcon structures and reinforced concrete (B25).

From the graph we can say about the need to increase the size of the cross section of the bending elements made of traditional reinforced concrete, for the perception of similar destructive load.

According to [13], for the selection of the cross section, we set the width of the element and select its height, by analogy with the tested samples, we retain the ratio \( b / h =1/2 \).

As a result of the calculation stated in [13], we obtain the values of \( h_0 \) and adding to it the value of the protective layer we obtain \( h \). The results of section selection are given in table 6.
| Beam code     | The diameter of the rods | h₀, (mm) | a, (mm) | h, (mm) | b, (mm) |
|--------------|--------------------------|---------|--------|--------|--------|
| BR - 0,8 (8) | 8                        | 122,6   | 15     | 138    | 60     |
| BR - 1,25 (10) | 10                      | 133,3   | 15     | 149    | 75     |
| BR - 1,8 (12) | 12                      | 142,1   | 15     | 158    | 80     |
| BR - 2,5 (2×10) | 2×10                   | 156,9   | 15     | 172    | 85     |
| BR - 3,6 (2×12) | 2×12                   | 172,9   | 15     | 188    | 90     |

3. Summary

From table 6 it is seen that for the perception of bending moment, which was destroyed fiberrubcon samples of the cross-sectional area of reinforced concrete beams made of concrete B25 with a similar reinforcement bar should be increased by 2.35 times, which in turn increases the weight and material consumption of the structure.

The effectiveness of the use in the construction of products and structures made of fiber rubber concrete, due to the favorable combination of its physical and mechanical characteristics, as well as the ability to obtain elements and structures with high load-bearing capacity. Especially effective is the use of rubber concrete with fiber in the manufacture and protection of elements, parts and structures exploitation in aggressive environments of various types: groundwater, sewage, precipitation, solar radiation, industrial products, etc.

Bending elements of rectangular cross-section with the addition of fibers and reinforced with non-stressed reinforcement, can be used as:
- floor beams and flooring, lintels of a door, window or other openings of buildings and structures, where the presence of aggressive environment of industrial or other origin;
- as bending structural elements of bridges and Railways;
- elements of foundations (in particular, foundation beams) exploitation under aggressive groundwater

The use of reinforced fiber rubber concrete in load-bearing structures due to its high durability leads to a reduction of material and weight of structures. This helps to reduce the cost of production and exploitation of building structures (in the construction of new and reconstruction of existent buildings and constructions), the addition of fiber in the structure allows to increase the crack bending moment and destructive bending moment, and high chemical resistance ensures life of the structure and reliable work throughout the period of exploitation in conditions of different aggressive environments.

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