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CRACK RESISTANCE OF REINFORCED CONCRETED AND REINFORCED RUBBER CONCRETE BEAMS

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ABSTRACT

The issue of the appearance and development of cracks, as well as an increase the cracking moment is of particular importance for bending elements operating under aggressive environmental conditions. In structures without cracks, steel reinforcement operates in fairly favorable conditions. However, when cracks appear in the sections of the structural element, the reinforcing bar is exposed to aggressive environmental influences, the voltage drop across the reinforcement also increases, etc.

In reinforced concrete structures, tensile stresses are perceived by reinforcing bars, an increase in the content of longitudinal reinforcement in the section leads to some increase in crack resistance of structures, however, an increase in the percentage of longitudinal reinforcement causes a number of undesirable phenomena such as increased consumption of reinforcement and increased weight of the structure. Also, the introduction of reinforcement into the concrete body does not eliminate such disadvantages of concrete as susceptibility to corrosion, low elasticity, low tensile strength and tensile strength. The use of polymer concrete improves these properties of reinforced concrete structures, while the density of fiber rubcon and rubcon is slightly lower than that of traditional concrete, and, consequently, the weight of structures made of this polymer concrete.

Keywords: *beam; crack-resistance, deformation, fiber rubcon, rubcon*

INTRODUCTION

As a result of studies of rubber concrete [1,2] and structures based on it [3,4,5,6,7,8], including reinforced rubcon bending elements of rectangular cross section [3,4] and T-sections [5], the authors confirmed the possibility of using structures based on this polymer concrete, the type of sensors was established to obtain an adequate picture of the distribution of deformations in the sections of the element. Also, methods have been proposed for using polymer concrete only in the tensile zone to protect steel reinforcement [6] or a polymer casing to protect concrete from aggressive environmental influences and increase the strength of the tensile zone [7,8,9].

Successful methods are known for increasing the strength of the tensile zone of bending elements by using carbon fiber tapes as external reinforcement [10,11], and in these studies, a method for increasing the strength of the tensile zone by the combined use of fiber reinforcement and external - carbon fiber tapes is proposed. Researchers engaged in the addition of steel fiber to concrete structures as a dispersed reinforcement [12,13], as a result of which it was proven that the addition of steel fiber together with longitudinal reinforcement has a positive effect on the crack resistance of an element.

METHODS

The technique of experimental studies of rubcon bending elements with mixed reinforcement is presented in the article [14], it also corresponds to the method of testing bent reinforced concrete elements with dispersed reinforcement, given in the articles [15]. The formation of normal cracks in the tested beams was determined by the testimony of strain gauges located on the lower surface of the bending element. The load at which normal cracks appeared in the material of the tensile zone was determined as follows: the strain gauge along which or near which the crack passed showed an abrupt increase in the relative tensile deformations.Figure 1 shows a general view of a prepared beam installed for testing to a testing machine.

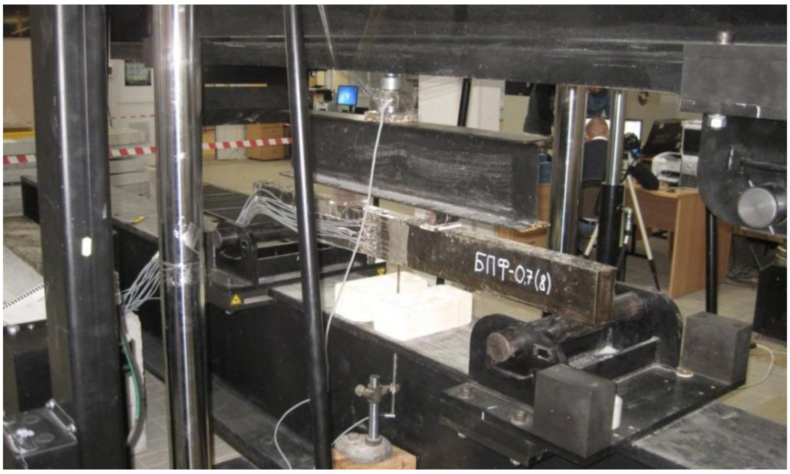

Figure 1 General view of the beam prepared for testing

The average results for each series of tested rubcon bending elements with mixed reinforcement are presented in table 1.

Table 1 Results for each series of tested rubber concrete beams

Beams' Cipher	A_s, cm^2	μ, %	h_f, mm	M_{crc}	M_{ult}	M_{crc}/M_{ult}
BRF-0	0	0,0	120	2,5	2,5	1,0
BRF-8	0,503	0,8	120	2,11	3,78	0,6
BRF-10	0,785	1,23	120	2,4	5,1	0,48
BRF-12	1,131	1,8	120	2,45	6,77	0,36
BRF-2x10	1,57	2,47	120	2,50	8,77	0,28
BRF-2x12	2,26	3,55	120	2,51	11,28	0,22
BRF-2x14	3,08	4,94	120	2,7	15,1	0,18
BRR-0	0	0,0	0	1,9	1,9	1,0
BRR-8	0,503	0,78	0	1,45	2,96	0,49
BRR-10	0,785	1,26	0	1,48	4,28	0,35
BRR-12	1,131	1,83	0	1,52	5,8	0,26
BRR-2x10	1,57	2,52	0	1,76	7,82	0,23
BRR-2x12	2,26	3,58	0	1,84	10,3	0,18
BRR-2x14	3,08	4,93	0	1,86	14	0,13
BRRF-0	0	0,0	90	2,3	2,3	1,0
BRRF-8	0,503	0,8	90	1,95	3,67	0,6
BRRF-12	1,131	1,78	90	2,2	6,3	0,37
BRRF-2x12	2,26	3,52	90	2,3	10,87	0,21
BRRF-2x14	3,08	4,98	90	2,5	14,8	0,17

Note: μ - percentage of longitudinal reinforcement, h_f - fiber reinforcement zone height (from the lower edge), M_{crc} – cracking moment, M_{ult} – breaking bending moment, M_{crc}/M_{ult} - relative level of cracking.

RESULTS AND DISCUSSION

Graphs of the relationship between the cracking bending moment and the height of the fiber reinforcement layer are shown in figure 2. The cracking bending moments of the normal sections of rubcon (BRR), fiber rubcon (BRF), layered fiber rubcon (BRRF) bending elements in relation to the percentage of longitudinal reinforcement and comparison with bending moments of crack formation sections of reinforced concrete (BRC) bending elements are shown in Figure 3.

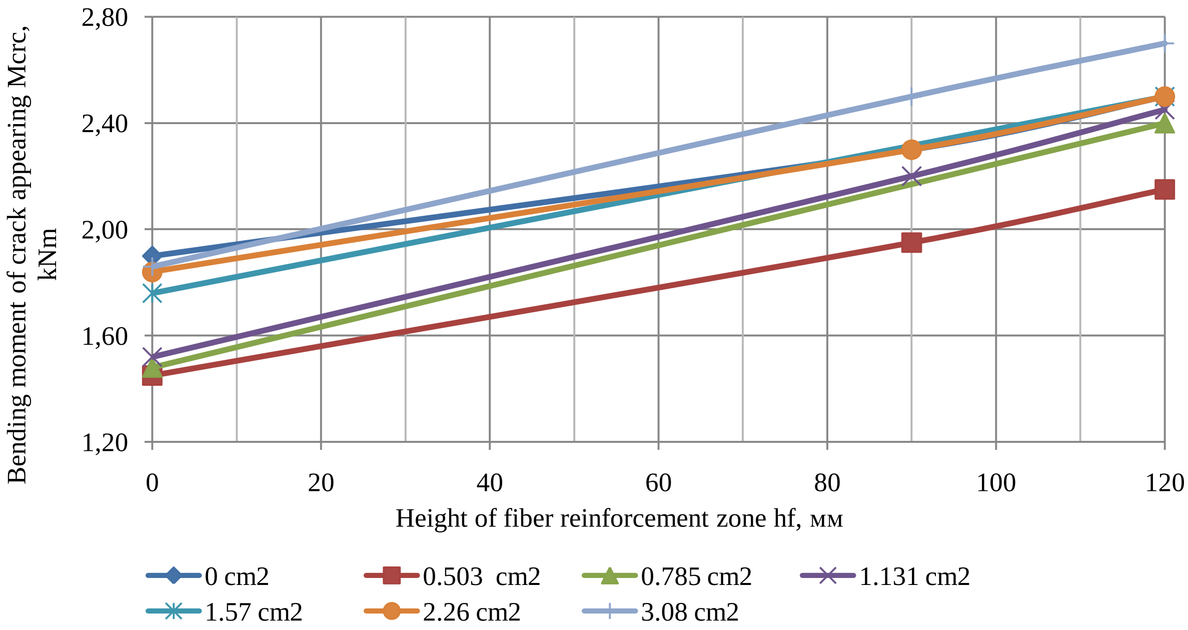

Figure 2 Bending moments of crack formation of rubcon beams with mixed reinforcement in relation to the height of the fiber reinforcement layer

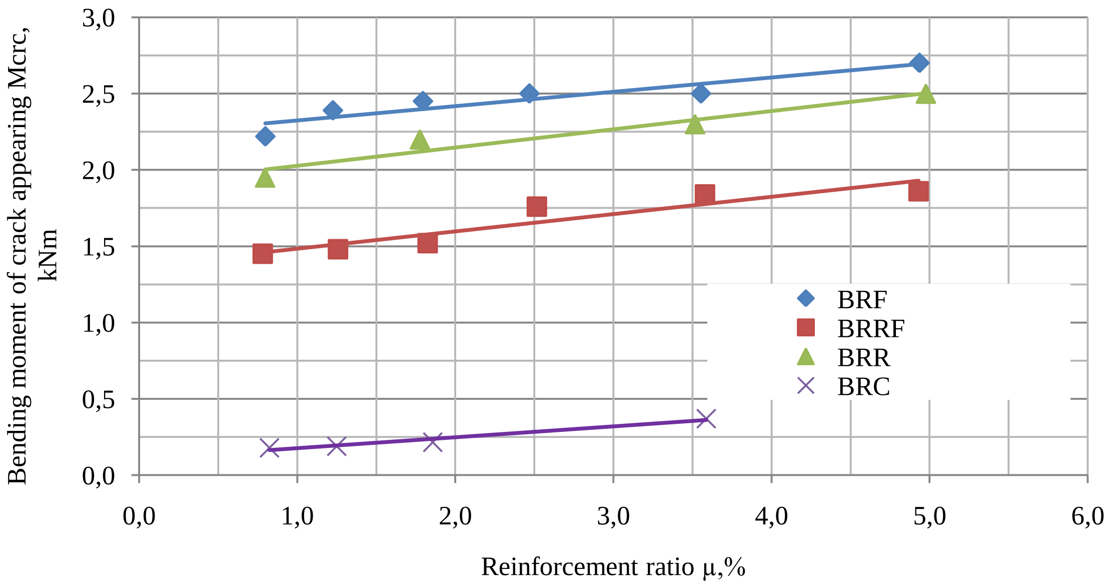

Figure 3 Moments of crack formation of tested beams in relation to the percentage of longitudinal reinforcement

It is important to note that in fig. 3 experimental beams without rod reinforcement are excluded, since they distort the overall picture of crack appearing of beams that collapse along the tensile zone. According to the results of testing rubcon beams with mixed reinforcement, it was found that the introduction of fiber only into the tensile zone most significantly increases the value of the crack formation load compared to elements without dispersed reinforcement. Moreover, this method of reinforcing only the tensile zone in some test series had a similar effect on crack resistance, in comparison to beams with dispersed reinforcement over the entire cross-sectional area. It is also clear from the analysis of the graphs in figures 2 and 3 that the height of the fiber reinforcement zone has a similar effect on crack resistance with the percentage of longitudinal reinforcement.

A comparison of the cracking moments of the fiber rubcon, rubcon bending elements and the layered fiber rubcon bending elements (figure 3) shows that the cracking moments of the fiber rubcons bending elements exceed the cracking moments of the rubcon and layered fiber rubcon bending elements. With a percentage of longitudinal reinforcement of 0.8% and a height of the fiber reinforcement layer of 120 mm, the cracking moments of the fiber rubcon bending elements exceed the cracking moments of rubcon bending elements with a percentage of longitudinal reinforcement of 0.78% and the height of the layer of fiber reinforcement 0 mm by 1.12 times, and layered fiber-reinforced elements with a percentage of longitudinal reinforcement of 0.8% and a layer height of fiber reinforcement of 90 mm, 1.08 times.

With a percentage of longitudinal reinforcement of 4.94% and a fiber reinforcement layer height of 120 mm, the cracking moments of the fiber rubcon bending elements exceed the cracking moments of rubcon bending elements with a percentage of longitudinal reinforcement of 4.93% and a fiber reinforcement layer height of 0 mm by 1.45 times, and layered fiber rubcon elements with a percentage of longitudinal reinforcement of 4.98% and a layer height of fiber reinforcement of 90 mm, 1.08 times. In this case, the value of the load before the crack appearing on rubcon beams exceeds the load on the reinforced concrete beams up to 8 times, the value of the load before the crack on the fiber reinforced concrete beams exceeds the load on the reinforced concrete beams up to 12.5 times.

The insignificant difference in the bending moments of fiber rubcon crack formation compared to the bending moments of the crack formation of the layered fiber rubcon beams is explained by the fact that the strength of the material of the tensile zone for both series of elements is almost the same, and, as can be seen from graphs 3, the effect of rod reinforcement on the value of the crack formation load is almost the same. The difference in the bending moments of the fiber rubcon crack formation compared to the bending moments of the rubcon beam cracking is explained by the fact that the tensile zone material strength for the fiber rubcon series of elements is higher than that of the rubcon series.

An analysis of the graphs of the relationships between the cracking bending moments and the height of the fiber reinforcement layer (figure 2) shows that for small percentages of longitudinal reinforcement (for example, beams with $\mu = 0.8\%$), the relationship between the cracking bending moments and the height of the fiber reinforcement layer is linear. For beams with a percentage of longitudinal reinforcement $\mu = 4.95\%$ with an increase in the height of the fiber reinforcement zone from 90 mm to 120 mm, the cracking moment increases by 8.0%.

Based on the above analysis, it can be said that fiber reinforcement of only the tensile zone can be used as reinforcement of rubcon structures with insignificant loss of bearing capacity until cracks are formed, this reinforcement method will reduce the consumption of dispersed reinforcement fibers while maintaining the necessary requirements for the thermal resistance of bending elements. However, this method of reinforcing increases the complexity of manufacturing a beam element.

The increased crack resistance of rubcon bending elements compared with reinforced concrete is primarily due to the high strength and deformation of rubcon under tension. It is known that the structure of a reinforced concrete element has a sufficiently large number of defects and various inclusions, which play the role of stress concentrators and significantly affect the decrease in the strength of the material.

The increased crack resistance of the bending fiber rubcon elements compared to the rubcon elements is explained by the increased strength and deformation of fiber rubcon due to the addition of dispersed reinforcement, which is well observed as a result of testing the rubcon and fiber rubcon beams. The bending moment of crack appearing of beams with dispersed reinforcement exceeds the bending moment of crack appearing of beams without dispersed reinforcement by an average of 1.47 times.

Relationships between the relative level of crack resistance in a normal section and the percentage of longitudinal reinforcement μ are presented in fig 4.

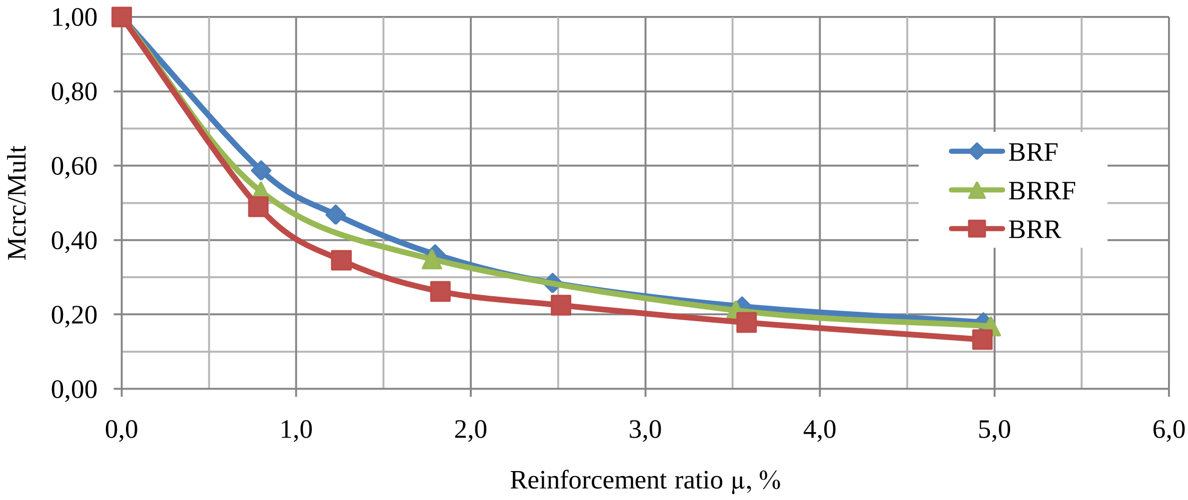

Figure 4 Relationship between the relative level of crack resistance of normal sections of rubcon beams with mixed reinforcement and the percentage of longitudinal reinforcement

The results of experimental studies show that with an increase in the percentage of longitudinal reinforcement, the effect of increasing crack resistance decreases. This is explained by the fact that with a high percentage of longitudinal reinforcement, a significant part of the force at the time of crack appearing is perceived by the reinforcement and only a small fraction of the load is transferred to the manufacturing material of the beam, in addition, with an increase in the percentage of longitudinal reinforcement, the amount of polymer concrete in the tensile zone decreases.

The number of normal cracks at the entire loading stage, up to failure, in rubcon beams with mixed reinforcement is significantly less than in reinforced concrete beams. According to the test data, the number of cracks in the fiber rubcon beams is varied from 1 to 10, in rubcon beams, it's varied from 1 to 10, in the layered fiber rubcon beams, it's varied from 1 to 9, and in reinforced concrete beams, from 6 to 9 and distributed along the entire length of the beams.

The conducted experimental studies allowed us to determine three stages of the formation of normal cracks in rubcon bending elements with mixed reinforcement. The first stage is characterized by a violation of the regularity of the distribution of deformations in the material of the tensed plane — deformations in the place where cracks subsequently form, increase more intensively than in neighboring sections.

The second stage is associated with the formation of cracks in these sections. In this case, deformations in the reinforcing bar and in the extreme tensile fiber explosively increase. The height of the compressed zone is reduced. At the third stage, with increasing load, cracks develop along the section height. In this case, new cracks form in neighboring sections up to the destruction of the element.

Based on the foregoing, it can be said that the longitudinal reinforcement is more influenced by the crack opening width, and the height of the dispersed reinforcement zone has a greater effect on the moment of crack formation and the "behavior" of cracks under load.

CONCLUSION

It is worth noting that the process of normal cracking in fiber rubcon beams is associated with reaching the tensile strength of the fiber rubcon, with a further increase in the load, smooth crack opening occurs, up to the destruction, the extension of metal cord filaments from the body of rubcon does not occur.

The process of formation of normal cracks in rubcon beams is associated with reaching the tensile strength of rubcon, with a further increase in load, crack opening occurs more sharply due to the absence of dispersed reinforcement.

The addition of fiber increases the value of the bending moment of cracking by 35 - 58% in the bending element, thereby increasing the percentage of utilization of the bearing capacity without the formation of normal cracks. What is an essential parameter when using structures with increased crack resistance requirements.

The cracking bending moment in rubcon beams exceeds the bending moment in reinforced concrete beams up to 8 times.

The cracking bending momentin fiber-reinforced concrete beams exceeds the bending moment in reinforced concrete beams up to 12.5 times.

Based on the studies, fiber rubcon beams are recommended as bending structures with increased crack resistance requirements.

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