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DEFORMABILITY OF RUBCON AND FIBRORUBCON BEAMS

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ABSTRACT

The study of the deformability of building structures, especially bending elements, is an integral part of a full study of structures, because it is often the deformability determines the size of the cross section of the element, to ensure the necessary rigidity of building structures. For beam elements, the most important during exploitation are vertical displacement – deflections.

For application (especially under the influence of aggressive environment) as a material of production of the building structures we offer rubber concrete-polymer concrete which has favorable deformation and strength characteristics, high adhesion to metal surfaces. It is important to note that the composition of fibrorubcon used industrial waste such as fly ash and fibers steel cord. It was established experimentally that the strength of fibrorubcon corresponds to the class of high-strength concrete, but the modulus of elasticity of rubcon corresponds to the modulus of elasticity of traditional concrete. To study the deformability of rubcon and fibrorubcon bending elements we have made a beam with a longitudinal reinforcement percentage μ = 0...8.4%.

The beams were tested for pure bending – the most characteristic type of loading for such elements. On the basis of the tests, a limit on the percentage of longitudinal reinforcement to satisfaction the requirements of the current standards for maximum deflections of fibrorubcon and rubcon beams was set.

Key words: *beam, deflection, deformability, fibrorubcon, rubcon*

INTRODUCTION

The use of polymer concrete building structures as an alternative to reinforced concrete elements has several advantages, such as increased strength and crack resistance of the structures due to the high physico-mechanical characteristics of the material of manufacture. However, an important factor for the normal exploitation of bending elements is satisfaction of the requirements for the limit vertical displacements – deflections.

Rubcon – polymer concrete on the basis of liquid rubbers or in other words rubber concrete with high strength characteristics. The optimal composition had obtained on the basis of studies of the properties of rubber concrete [1], as well as rubber concrete with dispersed reinforcement (fibrorubcon) [2,3], it is presented in Tables 1,2. It is important to note that the composition of fibrorubcon use industrial waste such as fly ash and fiber steel cord.

It was established experimentally that the strength of fibrorubcon corresponds to the class of high-strength concrete, but the modulus of elasticity of rubcon corresponds to the modulus of elasticity of traditional concrete, which can be seen from Table 3.

Table 1. The composition of rubber fiber concrete

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	51.3
Fiber from metal-cord waste (fiber)	2.5

Table 2. The composition of rubber concrete

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	55.3

Table 3. Physico-mechanical properties of concretes

Properties	Rubcon	Fibrorubcon	Concrete B25
Compressive strength, (MPa)	80	90	25
Tensile strength, (MPa)	9-11	12-13	1.55
The modulus of elasticity, (MPa)	26000-27000	29000-30000	30000
Poisson ratio	0.3	0.3	0.2

It should be noted that the modulus of elasticity affects the deformability of building elements made of this polymer concrete, which can also be seen in [4,5,6]. The prerequisites for studying fibrorubcon bending structures are presented in [5].

We would also like to note that this polymer concrete has almost universal chemical resistance, which is determined on the basis of the analysis of [7].Chemical resistance coefficients are given in Table 4.

Table 4. Coefficients of chemical resistance

Type of aggressive media	Coefficients of chemical resistance	
	After 1 year of exposure	Projected after 10 years
20 % solution of sulphuric acid	0.95	0.95
3 % nitric acid solution	0.8	0.7
10 % citric acid solution	0.9	0.8
20 % solution of caustic soda	0.95	0.95
10 % solution of caustic potassium	0.8	0.65
Saturated sodium chloride diesel	0.9	0.8
Combustible diesel	0.95	0.95
Water	1	0.99

Consequently, the structures made of this polymer concrete will also have high corrosion resistance to aggressive environments. Therefore, the recommended application area of these structures is industrial construction.

METHODS

To study the deformation and determine the maximum percentage of longitudinal reinforcement in fibrorubcon beams to satisfaction of requirements of AITC Recommended Deflection Limits and Russian's SP was manufactured and tested beam of rectangular section with longitudinal reinforcement. The variable parameter was chosen percentage of longitudinal reinforcement μ = 0...8.4%.

The geometric parameters of the beams were assigned based on the analysis of literature sources [4,5,6,8,9,10,11] 60x120mm, where the larger size is the height of the section, the total length of the element is 1.4 m. Based on the analysis of work [11], the deflectometer is set only in the middle of the span.

The reinforcement of the compressed zone in the zone of pure bending of the beam element is absent. It should be noted that the fiber is located chaotically.

This is due to the fact that microcracks can form not only in the plane of the bending moment. Also, the use of equipment for the direction and location of steel fiber will complicate and increase the cost of the production process.

The beams were tested for pure bending – the most characteristic type of loading for such elements [9,10,11,12,13,14,15,16], this test scheme also corresponds to the papers devoted to the study of the "work" of rubcon beams under load [4,5,6].

The scheme of experimental test beams, the scheme of the reinforcing frame and scheme of the location deflectometer to determine the ultimate deflection in the destruction of the element are shown in Figure 1. Figure 1 also shows the cross section of the experimental beam.

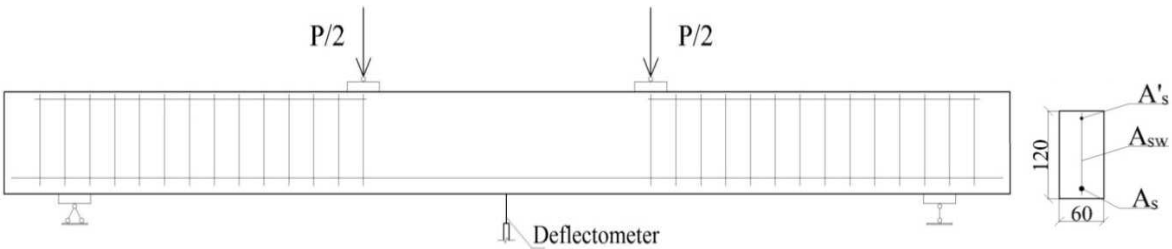

Figure 1. The testing scheme of the bending elements. The cross-section of the bending elements

The deflection measured by an electron-type deflectometer in the middle of the span was accepted by the criterion of deformability of the bending elements. As a result of testing 8 series of fibrorubcon beams (BRF cipher) and 8 series of rubcon beams (BRR cipher), data on limiting deflections were obtained, which are summarized in Table 5.

Analysis of the results presented in Table 5 showed that the value of deflection in the rubcon and fibrorubcon beams increases with increasing percentage of reinforcement.

We have also produced and tested reinforced concrete beams similar in their geometric parameters and the percentage of reinforcement on polymer concrete beams. The material of the beam was concrete class B25. The obtained values of vertical displacements are summarized in Table 6.

Table 5. The values for the maximum deflections of the polymer concrete beams

Beam cipher	Percentage of longitudinal reinforcement μ,(%)	f, (mm)
BRF - 0	0.00	2.42
BRF - 8	0.80	6.28
BRF - 10	1.23	9.24
BRF - 12	1.60	11.1
BRF – 2x10	2.47	10.6
BRF – 2x12	3.55	12.15
BRF – 2x14	4.94	13.57
BRF – 2x16	6.26	16.62
BRF – 2x18	8.47	16.62
BRR - 0	0.00	1.02
BRR - 8	0.78	5.24
BRR - 10	1.26	7.26
BRR - 12	1.83	7.99
BRR – 2x10	2.52	10.8
BRR – 2x12	3.58	11.0
BRR – 2x14	4.93	15.23
BRR – 2x16	6.38	15.28
BRR – 2x18	8.30	14.62

Table 6. The values for the maximum deflections of the concrete beams

Beam cipher	Percentage of longitudinal reinforcement μ,(%)	f, (mm)
BRC - 8	0.82	6.97
BRC - 10	1.25	7.44
BRC - 12	1.86	8.25
BRC – 2x12	3.59	8.53

RESULTS

On the basis of the test results, the graphs of the deflections of polymer-concrete and reinforced concrete beams on the relative level of loading were obtained, which are shown in Figures 2,3,4. Calculation of the ultimate deformations of building structures is an important part of the design of bending elements.

The requirements of building standards limit the value of deflection of structures, which leads to an increase in the size of the cross section to increase the rigidity of the structure, while the strength properties of the material of the structure when calculating the bearing capacity are not used 100%. Also, with large vertical displacements, the width of crack opening increases, which has a negative effect on the protection of reinforcement from corrosion.

Therefore, increasing the resistance of the bending structure to vertical displacement while maintaining the greatest load-bearing capacity is relevant. According to the standards, the maximum deflection for the floor beam with a span of 1.2 m. will be 9.5 mm this value is highlighted in Figures 2 and 3.

Analysis of the test results allowed us to determine that the vertical displacement of the beams depends on the percentage of longitudinal reinforcement. It is important to note that the area from 0.60 M / M_{ult} to 0.65 M / M_{ult} in Figures 3 and 4, is the area corresponding to the loads occurring in the process of exploitation [4].

The inflection point of the vertical displacement curves corresponding to the moment of crack formation divides the graph into two sections. On the first section the beam works elastically, the relationship between deflection and load is almost linear. After the appearance of cracks due to the decrease in the height of the compressed zone and the growth of cracks, the rigidity of the beams decreases, this causes a more intensive growth of deflections.

This phenomenon is most noticeable on rubber concrete beams without fiber reinforcement and with a low percentage of longitudinal reinforcement. The rate of growth of vertical displacements up to the destruction of each section of the graph is constant.

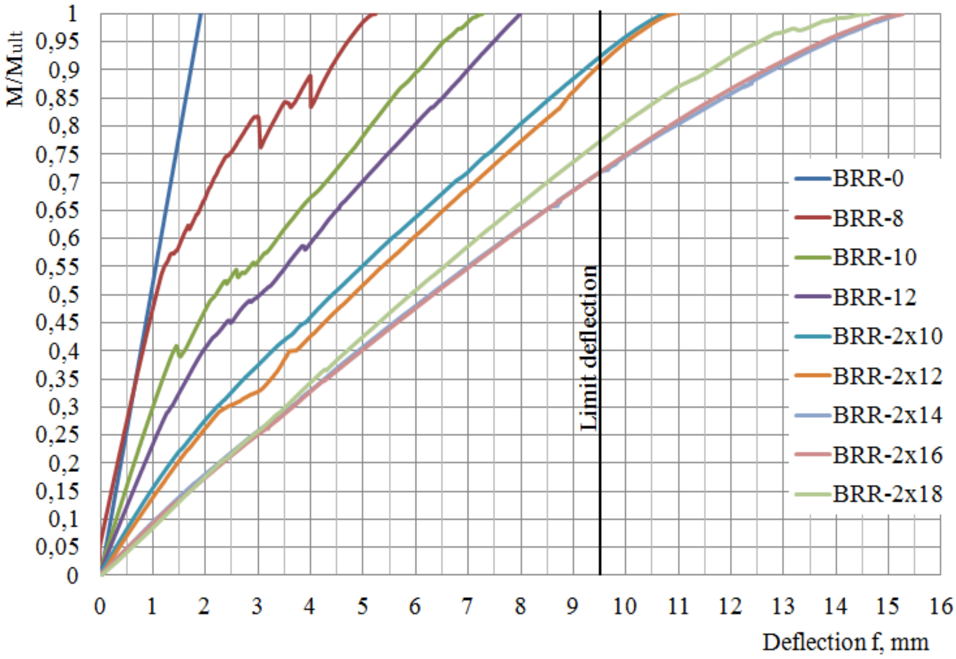

Figure 2. Relationship between the deflections of rubcon beams without fiber reinforcement and the relative level of loading

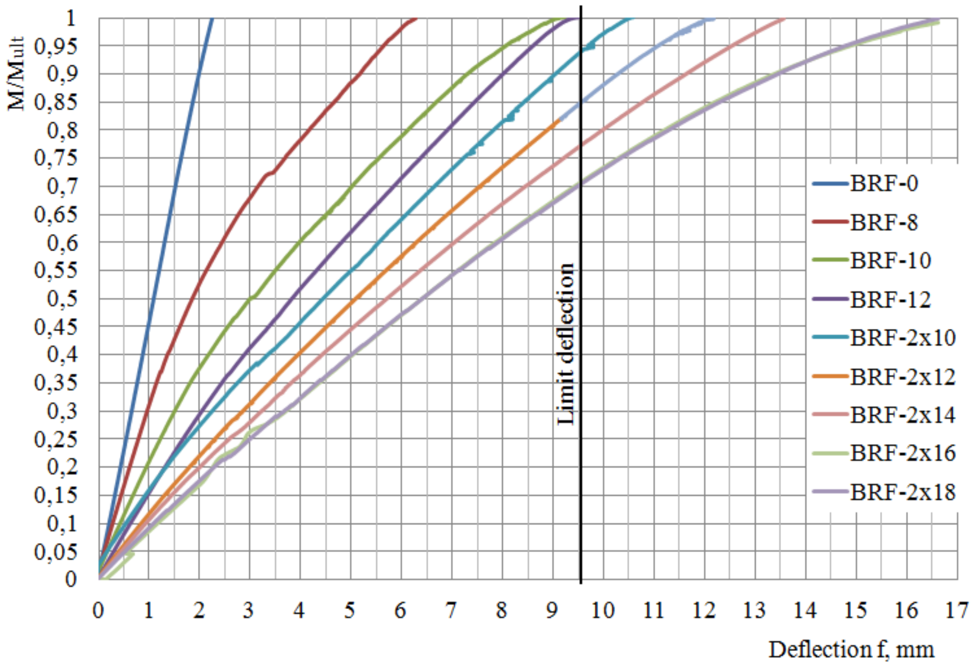

Figure 3. Relationship between the deflections of fibrorubcon beams with fiber reinforcement and the relative level of loading

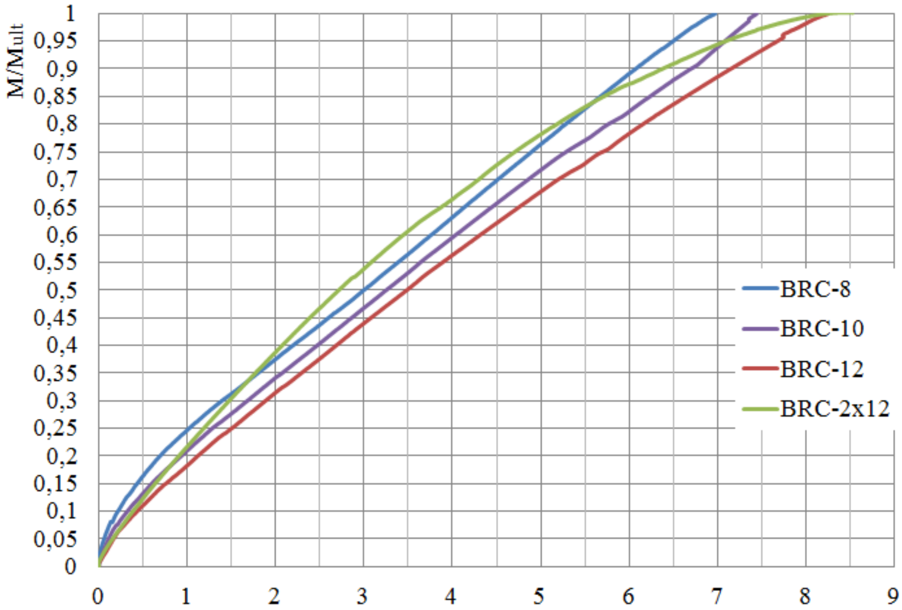

Figure 4. Relationship between the deflections of reinforced concrete beams and the relative level of loading

DISCUSSION

The analysis of graphs of the dependence of deflection from the bending moments of beams with various percent of longitudinal reinforcement and the comparison of deflections rubcon, fibrorubcon beams with similar deflections of reinforced concrete beams shows that disperse reinforcement increases the deformability (deflection) structures.

The greatest effect of increasing the deformability depending on the presence of dispersed reinforcement is observed at a small percentage of longitudinal reinforcement. It is obvious that with the increase in the percentage of longitudinal reinforcement, the vertical displacements of the bending elements also increase. However, for beams with a large percentage of longitudinal reinforcement, the lines of the graphs practically repeat each other, this statement is more relevant to beams, the destruction of which is fragile (BRR-2x18, BRF-2x18) and to the last in a series of beams destroying on the tensile zone (BRR-2x16, BRF-2x16).

This suggests that the destruction of the compressed zone is not due to the occurrence in the compressed zone of the plastic hinge associated with low rigidity, but with the achievement of the material design of the actual ultimate compressive strength. It is also important to note that in beams with dispersed reinforcement, in addition to increased deformability, there is also a smoother growth of deflections, i.e. the outlines of the graphs are more rectilinear.

This means that the cracks open smoothly, which suggests the working of fiber in an already formed cracks. Smaller deflections in rubcon beams under the action of external load compared to deflections in fibrorubcon beams due to the fact that the rubcon elements there is an earlier appearance of cracks, also, due to the absence of dispersed reinforcement, the reinforcing bar is more intensively included in the work, as a result of which the yield strength of the reinforcing steel is reached at a lower load.

The outlines of vertical displacement graphs from the relative loading level of reinforced concrete structures are similar to the outlines of graphs for polymer concrete structures this suggests to the similar rigidity of the test structures. At the same time the value of the modulus of elasticity of rubcon and fibrorubcon is lightly lower than the value of the modulus of elasticity of the used concrete class.

This observation is due to the fact that the appearance of cracks in reinforced concrete structures occurs at an early stage of loading, as a result of which the rigidity of the section decreases.

CONCLUSION

As a result of comparing the work of reinforced concrete and polymer concrete structures according to the current standards, it can be concluded that with a large percentage of longitudinal reinforcement (μ> 1.8%), second limit states occur in polymer concrete building structures, and only then the first limit states.

Maximum allowable deflection in beams with μ>1.8% occurs at a loading level of 0.7 to 0.95, for example, for BRR beams with a percentage of longitudinal reinforcement of 4.93%, the maximum allowable deflection occurs at a relative loading level of 0.71, for BRF beams with a percentage of longitudinal reinforcement of 4.94% the maximum allowable deflection occurs at a relative loading level of 0.77.

In the last beams, in a series of destruction on the tensile zone and in the beams destroying on the compressed zone, achievement of a limit deflection corresponds to the relative level of loading of 0.71-0.77. This means that the limitation on vertical displacement makes the reserve bearing capacity in the exploitation of polymer concrete bending structures with a high percentage of longitudinal reinforcement up to 29%. In other words, if the percentage of longitudinal reinforcement in the bending structures of rubcon is high, the determining calculation will be the calculation of the limit deformations.

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