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RC BEAMS WITH AN MIDDLE PHASE OF REINFORCEMENT DAMAGE

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Abstract: This article presents the results of tests of real-size reinforced concrete beams with damaged A500C class reinforcement from 20 to 18 mm in diameter. To achieve this goal, 4 reinforced concrete beams with dimensions of 2100x180x140 mm were manufactured, two of them were control beams and two beams with damaged working fittings from 20 to 18 mm in diameter. The microhardness of the reinforcement with a diameter of 20 mm of class A500C was previously determined and it was established that the outer layer of the reinforcement is thermally strengthened. For heat-strengthened reinforcement, there is a weakening of the physical and mechanical characteristics over time, since corrosion of the surface strengthened layer can occur, as well as local weakening occurs in places of welding, which can be a source of damage formation and changes in the stress-strain state in this section. To establish the real stress-strain state of the reinforcement, tests were conducted on rods with an initial diameter of 20 mm and damaged from 20 to 18 mm, and a decrease in the physical and mechanical characteristics of the reinforcement was established. The next stage of the research was the testing of control and damaged reinforced concrete beams. As a result of the tests, it was established that the reduction of the bearing capacity occurs not only due to the reduction of the cross-section and, accordingly, the cross-sectional area of the working reinforcement, but also due to the reduction of the physical and mechanical characteristics of the reinforcement. it was found that reducing the transverse diameter of the reinforcement reduces the moment when the reinforcement flow is reached by 43%, and the moment when the most compressed concrete fiber is reached by 36%.
Keywords: reinforced concrete beams, actual size of samples, bending, damage, thermal-strengthened reinforcement

1. INTRODUCTION

Technical materials used in construction have an internal structure, the presence of different scales of structural elements, the interaction of which determines their strength characteristics, stiffness parameters, as well as the reaction to external influences,

operational loads, natural conditions (temperature, environment, etc.) (Anriichuk et al. , 2021, Brachaczek and Gałuszka, 2023; Dmytrenko et al., 2023; Katunský et al., 2015; Grydzhuk et al., 2022).
To establish the physical and mechanical state of the material, taking into account their changes in the structural elements, appropriate adequate objects, scheme calculations and models are created (Blikharskyy et al., 2021; Bobalo et al., 2021, Dorofeyev and Pushkar, 2023, Kotes et al. , 2020). At the same time, the properties and interactions of real objects that are irrelevant for consideration are not taken into account, that is, the behavior of some idealized materials is actually studied. It should also be noted that materials with different physico-mechanical properties are used in various designs and their changes occur under the influence of the environment. In particular, reinforced concrete beams by their design have different components, both in terms of mechanical characteristics and in terms of their operation during operation (Kotes et al., 2022; Vatulia et al., 2020; Pietrzak, 2024; Stechyshyn et al., 2015). As the service life increases, the strength parameters of concrete increase, and the deformation parameters may decrease. For heat-strengthened reinforcement, a weakening of the physical and mechanical characteristics is observed over time, since corrosion of the surface strengthened layer can occur, as well as local weakening occurs in places of welding, which can be a source of damage formation and changes in the stress-strain state in this section (Blikharskyy et al., 2019; Dmytrenko et al., 2016; Kos et al., 2017; Kotes et al., 2023). The simplest physical model of a solid body for determining the stress-strain state under given external influences is a solid medium with given physical and mechanical properties. This means that each volume is endowed with certain properties, in particular density, deformability and strength, which are characteristic of macrovolumes. If such properties are the same at all points, then the body is called homogeneous.
Practically, for calculations, the body is assumed to be homogeneous. During long-term operation, structural elements that have different materials will change their bearing capacity to resist deformation and destruction with certain features of changes in physical and mechanical characteristics (Lenkovskiy et al., 2017; Lipiński, 2021; Lipiński and Wach, 2020; Świt et al., 2023; Ostach et al., 2011).
Given that reinforced concrete structures are made from concrete components and reinforcement, which have different mechanical characteristics and depend on load conditions, service life, external influences, etc. it is difficult to assess their durability in the presence of damage.
The distribution of deformations along the height of the beam changes from tensile in the lower zone to compressive in the upper zone (Zahuranec et al., 2023). Stresses will also change, affecting the stress-strain and limit state of the beam. Achieving limit states for concrete in stretched and compressed zones because their physical and mechanical characteristics are different.
The use of heat-strengthened reinforcement in the manufacture of beams and the assessment of the period of safe operation requires an assessment based on data on the stress-strain state in local volumes, since the physical and mechanical characteristics in the cross-section are variable.

2. MATERIALS AND METHODS

In this article, 4 reinforced concrete beams of real dimensions of 2100x180x140 mm were tested (Fig. 1).

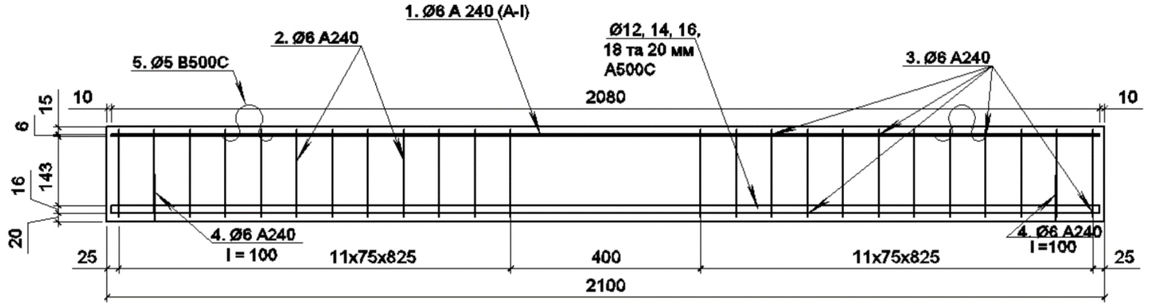

Fig. 1. Sizes and reinforcement of tested samples

To ensure the strength of the inclined sections, transverse reinforcement with a diameter of 6 mm, grade A240, with a step of 75 mm was designed. In the compressed zone, structural reinforcement of 2 rods with a diameter of 6 mm of class A240 is designed. Reinforcement is made with 1 rod with a diameter of 20 mm, class A500C.

After determining the microhardness of reinforcement with a diameter of 20 mm, class A500C, it was established that with a decrease in the outer diameter from a diameter of 20 mm to 16 mm, not only the cross-sectional area decreases, but also the physical and mechanical characteristics of the reinforcement (Fig. 2).

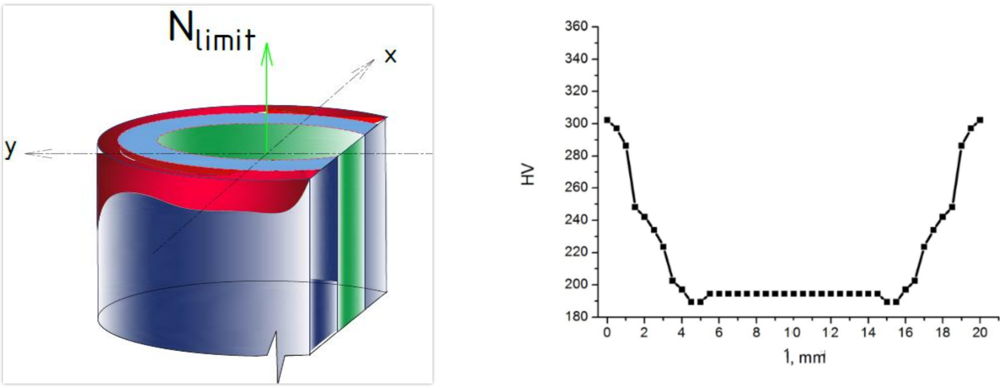

Fig. 2. Changes in the physical and mechanical characteristics of the reinforcement depending on the damage to the outer layer

At the all tests were used a professional VIC-3D system. In order to establish the real physical and mechanical characteristics of the reinforcement, undamaged and damaged rods were tested using the digital image correlation method (Fig. 3).

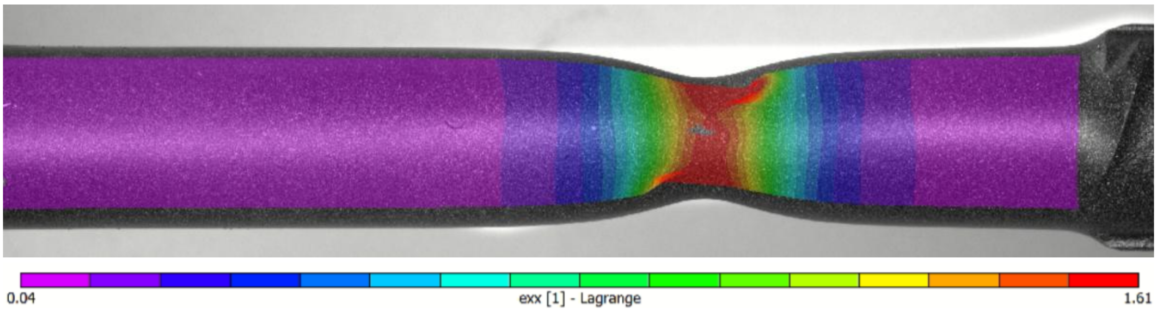

Fig. 3. Experimental tests of reinforcement with a diameter of 20 mm damaged to a diameter of 16 mm using the method of digital image correlation

As a result, test diagrams of undamaged reinforcement samples with a diameter of 20 mm and damaged samples from 20 mm to 16 mm in diameter were constructed (Fig. 4).

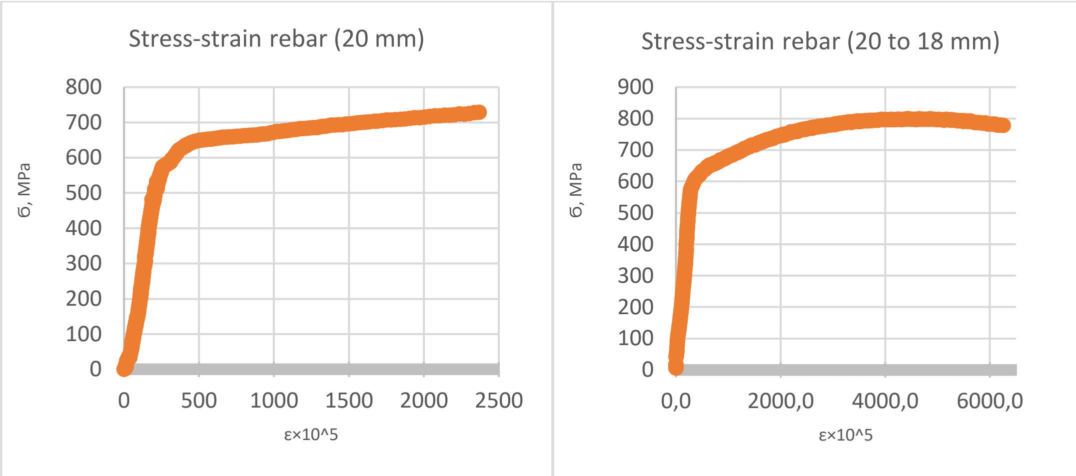

Fig. 4. Graphs of reinforcement strains with a diameter of 20 mm and damaged from a diameter of 20 to 18 mm

Therefore, two beams B-1 and B-2 were tested with 20 mm diameter working reinforcement and two beams with damaged working reinforcement from 20 mm to 16 mm diameter.
The beams were tested for the action of the bending moment, the forces were applied by two equally spaced concentrated loads at 2 points with a distance from the supports and between the forces in 1/3 of the span (Fig. 5).


Fig. 5. General view of the experimental setup and the location of the devices on the test reinforced concrete beams

To determine the deformations of compressed concrete and reinforcement, watch-type submicron indicators were used.

3. RESULTS AND DISCUSSION

Control experimental beams B-1 and B-2 were tested for static bending moment and it was determined that the moment at the beginning of yielding of the reinforcement was M_y=21.42 kNm, and the moment when the limit deformation of the most compressed zone of concrete was reached M_{cu}=22.9 kNm (Fig. 6).

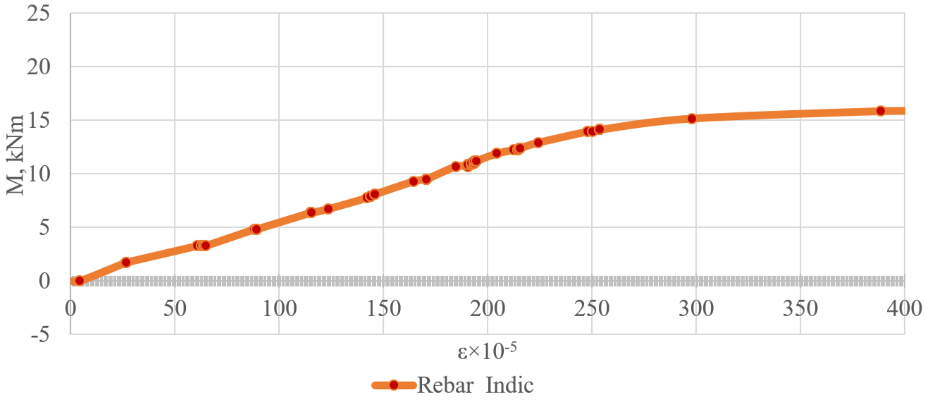

Fig. 6. Graph of reinforcement strains of control beams B-1 and B-2

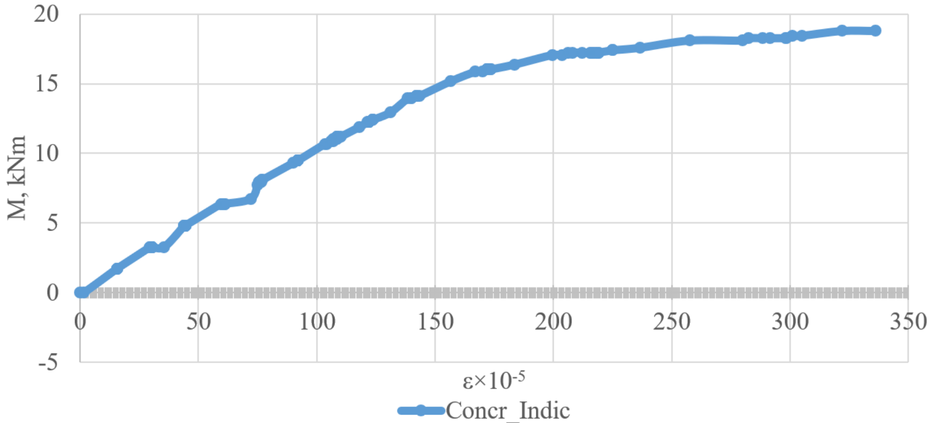

Fig. 7. Graph of strains of the most compressed concrete of control beams B-1 and B-2

In samples B-3 and B-4, the A500C class rebar is sharpened from a diameter of 20 mm to a diameter of 16 mm before concreting. The outer reinforced layer of the working reinforcement is sharpened along the center to an approximate length of 120 mm. Similarly, graphs of strains of reinforcement (Fig. 8) and strains of the most compressed concrete (Fig. 9) were plotted based on the test results.

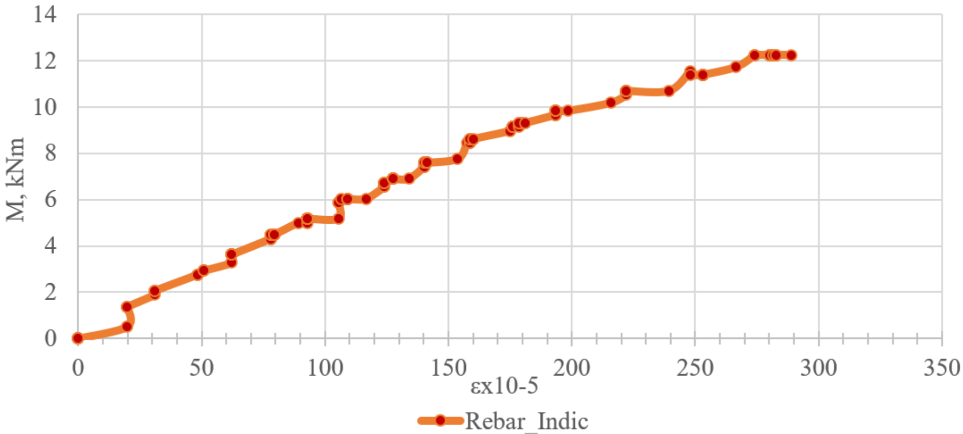

Fig. 8. Graph of strains of reinforcement of damaged beams B-3 and B-4

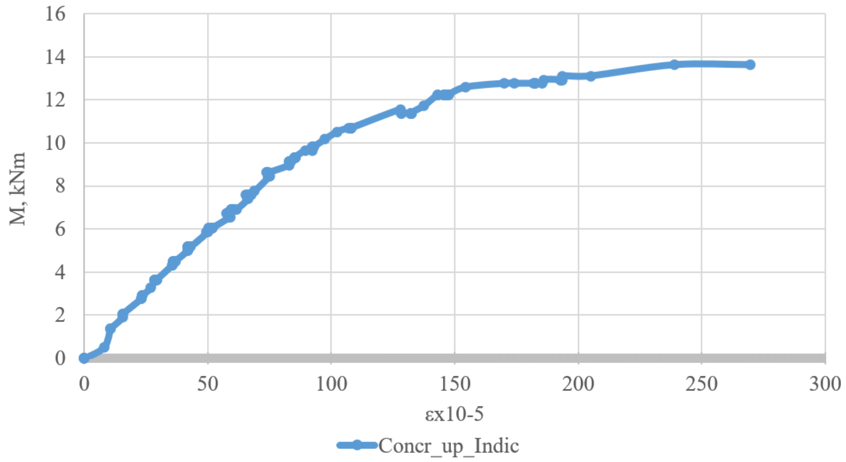

Fig. 9. Graph of strains of the most compressed concrete of damaged beams B-3 and B-4

In samples BP-1.5 and BP-1.6, the moment at which the beginning of the yield point was reached (ε_{yk}=273·10-5) was reached at M_y=12.24 kNm according to the readings of sub-micron non-conductive indicators.

After reaching the yield point, there is a sharp increase in the deformations of the concrete of the most compressed fiber. The ultimate deformation of the concrete of the most compressed fiber ε_{cu1}=263·10-5 is reached at the moment M_{cu}=13.62 kNm.

The general test results are shown in Table 1.

Table 1

Results of experimental studies

<table>
<tr><th>Beams</th><th>Diameter before damages</th><th>Diameter after damages</th><th>Yielding moment, kNm</th><th>Bearing Capacity moment, kNm</th><th>Yielding moment compare to B-1 та B-2, %</th><th>Bearing-capacity moment compare to B-1 та B-2, %</th></tr>
<tr><td>B-1</td><td rowspan="4">20</td><td>-</td><td rowspan="2">21.4</td><td rowspan="2">22.9</td><td rowspan="2">-</td><td rowspan="2">-</td></tr>
<tr><td>B-2</td><td>-</td></tr>
<tr><td>B-3</td><td>16</td><td rowspan="2">12.2</td><td rowspan="2">13.6</td><td rowspan="2">42.7</td><td rowspan="2">36.2</td></tr>
<tr><td>B-4</td><td>16</td></tr>
</table>

As a result of the obtained experimental studies, it was found that with a decrease in the cross-section of the working reinforcement, the moment at which the beginning of the yield point is reached and the limit values of the most compressed concrete fiber are reached. At the same time, a significant decrease is observed in samples with sharpening of the outer layer of reinforcement from a diameter of 20 to 18 mm, namely, it is 43% and 36%, respectively.

4. CONCLUSION

As a result of these studies, it was established that reducing the cross-sectional diameter of A500C reinforcement reduces not only the cross-sectional area, but also reduces the physical and mechanical characteristics. As a result of the research, 4 reinforced concrete beams, two control beams and two beams with damaged external reinforcement from 20 mm to 18 mm in diameter were tested. As a result of the tests, it was found that reducing the transverse diameter of the reinforcement reduces the moment when the reinforcement flow is reached by 43%, and the moment when the most compressed concrete fiber is reached by 36%. That is, the reduction of the transverse diameter of the reinforcement affects the reduction of the bearing capacity not only due to the change in the geometric parameters of the reinforcement, but also due to the decrease in the physical and mechanical characteristics of the reinforcement. The research data must be taken into account in the practical application and diagnosis of the stress-deformed state of reinforced concrete structures that are in use and have suffered damage during operation. Namely, it is necessary to take into account in the calculation not only the change in geometric dimensions, but also the decrease in stress when the yield strength of the reinforcement is reached.

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