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Experimental investigation of mechanical properties of A-III reinforcing steel bars with a diameter of 10 mm

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Abstract:

This paper presents the results of an experimental investigation into the mechanical properties of A-III reinforcing steel bars with a diameter of 10 mm intended for use in reinforced concrete structures. The study was carried out prior to testing reinforced concrete beams in order to determine the actual strength and deformation characteristics of the reinforcing steel used in the experimental program. Tensile tests were performed in accordance with the requirements of GOST 1497–84 using a universal testing machine. During the experiments, the maximum tensile load, ultimate tensile strength, yield strength, relative elongation, plasticity coefficient, and coefficient of variation were determined. The average values of the ultimate tensile strength, yield strength, and relative elongation were found to be 485 MPa, 405 MPa, and 23.165%, respectively. The experimental results were compared with the requirements of GOST 34028–2016 and demonstrated full compliance with the prescribed mechanical performance criteria. The coefficient of variation did not exceed 3.4%, confirming the high homogeneity and reliability of the investigated reinforcing steel. The obtained results indicate that the tested reinforcement possesses high strength, sufficient ductility, and stable deformation characteristics, making it suitable for application in flexural reinforced concrete elements subjected to static loading. The research findings can be used in the design, analysis, and experimental assessment of reinforced concrete structures and provide reliable reference data for evaluating the load-bearing capacity and serviceability of structural members.

Keywords:

intelligent transport system, ADAS, intersection safety, dynamic model, kinematic analysis, reaction time, stopping distance, accident probability, model adequacy

1. Introduction

In recent years, modern high-strength concretes, chemical modifying admixtures, and advanced technologies for the production of reinforced concrete elements have been increasingly applied in the construction industry. However, even when high-quality concrete is used, the operational reliability of structures largely depends on the mechanical properties of reinforcing steel. Therefore, the reliable determination of its strength and deformation characteristics is an essential stage in experimental studies of reinforced concrete structures.

In the design and analysis of flexural reinforced concrete elements, the key parameters include the yield strength of reinforcing steel, ultimate tensile strength, relative elongation, and the material's capacity for plastic deformation. These characteristics determine the onset of plastic deformation, redistribution of internal forces, failure behavior of structural elements, and their level of operational safety.

Determining the actual mechanical properties of reinforcing steel makes it possible to improve the accuracy of engineering calculations, ensure that analytical models adequately reflect the actual structural behavior, and assess the quality of the reinforcing steel used.

According to the requirements of the current regulatory standards (GOST 1497–84 and GOST 34028–2016), the mechanical properties of reinforcing steel must be verified by experimental tensile testing. Such tests make it possible to determine the main strength characteristics of the

material, assess its ductility and structural homogeneity, and verify its compliance with regulatory requirements. In addition, experimental investigations enable the identification of possible deviations in mechanical properties resulting from specific manufacturing technologies, heat treatment processes, or storage conditions of reinforcing steel.

The present study was conducted as part of an experimental program aimed at investigating the behavior of flexural reinforced concrete beams produced using locally available chemical admixtures. Prior to testing the reinforced concrete specimens, the mechanical properties of 10 mm diameter A-III class reinforcing steel used as the longitudinal reinforcement were investigated. Preliminary testing provided objective data on the actual strength and deformation characteristics of the reinforcing steel used in the experimental structural elements.

The aim of this study is to experimentally determine the mechanical properties of 10 mm diameter A-III class reinforcing steel by conducting tensile tests, to analyze the obtained results, and to assess their compliance with the requirements of current regulatory standards. The obtained data can be used in the design of reinforced concrete structures, experimental investigations, assessment of the load-bearing capacity of flexural elements, and improvement of calculation methods for reinforced concrete structures by taking into account the actual mechanical properties of the reinforcing steel used.

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2. Research methodology

The experimental investigation of the mechanical properties of 10 mm diameter A-III class reinforcing steel was carried out to determine its actual strength and deformation characteristics prior to testing the reinforced concrete beams. The obtained results were used as input data for the subsequent analysis of the load-bearing capacity and deformation behavior of the reinforced concrete elements.

The test specimens consisted of three samples of A-III class reinforcing steel with a nominal diameter of 10 mm. Prior to testing, the geometric dimensions of each specimen were measured, including the actual diameter, gauge length of the working section, and initial cross-sectional area. The gauge length was 300 mm for all specimens.

The tensile tests were performed using a GOST-TEST universal testing machine (serial No. 082020224) in accordance with the requirements of GOST 1497–84, “Metals. Methods of Tensile Testing.” Before testing, the specimens were carefully aligned and secured in the grips of the testing machine along their longitudinal axes to prevent eccentric loading. The load was applied smoothly and continuously at a constant rate until specimen failure, thereby ensuring the acquisition of a reliable load–deformation curve.

During the tests, the applied load and the corresponding deformation values were recorded automatically. Based on the experimental data obtained, tensile stress–strain curves were constructed, from which the maximum failure load, yield strength, ultimate tensile strength, and percentage elongation after fracture were determined.

The mechanical properties were calculated in accordance with the requirements of the applicable regulatory standards. The initial cross-sectional area was determined using the actual diameter of each specimen. The ultimate tensile strength was calculated as the ratio of the maximum failure load to the initial cross-sectional area. The yield strength was determined from the stress–strain curve as the stress corresponding to the onset of stable plastic deformation. The percentage elongation was calculated as the ratio of the increase in gauge length after fracture to the initial gauge length of the specimen.

To improve the reliability of the results, the tests were conducted on three independent specimens of the same nominal diameter. After completion of the tests, the mean values of each determined parameter were calculated, along with the coefficient of variation, which was used to characterize the degree of uniformity of the reinforcing steel under investigation.

The experimental results were compared with the requirements of GOST 34028–2016, which specifies the mechanical properties of reinforcing steel for reinforced concrete structures. The adopted testing methodology provides a high degree of reproducibility, enables an objective assessment of the strength and deformation characteristics of reinforcing steel, and can be applied in similar experimental studies of reinforced concrete structures.

The obtained mechanical properties were subsequently used in the calculations and analysis of the behavior of flexural reinforced concrete elements reinforced with the investigated steel.

3. Results and Discussion

The tests were conducted using a universal tensile testing machine in accordance with the requirements of GOST 1497–84. During the experimental study, three reinforcing steel specimens with a diameter of 10 mm were tested (Fig. 1).

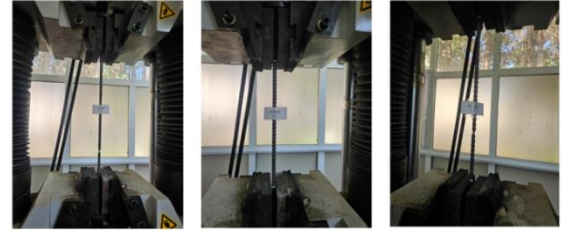


Fig. 1. Tensile Test of Reinforcing Steel Specimens

For each specimen, the initial cross-sectional area, maximum failure load, tensile deformation, and strength characteristics up to the point of failure were determined. Based on the experimental results, the main mechanical properties of the reinforcing steel were calculated and compared with the requirements of the applicable regulatory standards.

The tests were conducted in accordance with the requirements of GOST 1497–84 (Fig. 2), which provides a generally accepted methodological basis for determining the mechanical properties of metallic materials. The tests were performed using a GOST-TEST universal testing machine (serial No. 082020224). Reinforcing steel specimens with a diameter of 10 mm and a gauge length of 300 mm were used in each test.

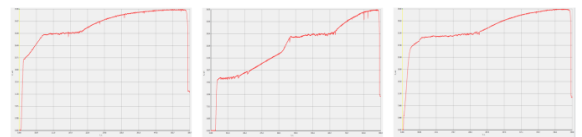


Fig. 2. Load–Deformation (P–Δ) Curves Obtained During the Tensile Testing of Reinforcing Steel Bars

During the tests, the main mechanical properties of the reinforcing steel were determined (Table 1), including the maximum failure load (P_{max}), percentage elongation at fracture (δ), ultimate tensile strength (σ_u), and yield strength (σ_y). The obtained values were used to evaluate the strength and deformation characteristics of the reinforcing steel under investigation.

Table 1
Main Parameters Determined During the Experimental Investigation

N_0	d_0 , mm	l_0 , mm	P_{max} , kN	δ , %	σ_B , MPa	σ_T , MPa
1	10.0 0	300. 0	37.856	22.2	482	395
2	10.0 0	300. 0	36.560	23.3	465	375
3	10.0 0	300. 0	39.803	23.9	507	446



Ср ед.	10.0 0	300. 0	38.073	23.1	485	405
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As can be seen from the test results, all the reinforcing steel specimens exhibited similar strength and deformation characteristics. The average maximum failure load was 38.073 kN, while the average ultimate tensile strength, yield strength, and percentage elongation were 485 MPa, 405 MPa, and 23.165%, respectively. The obtained results indicate a high degree of uniformity in the mechanical properties of the investigated reinforcing steel and confirm its compliance with the regulatory requirements for reinforcing steels used in reinforced concrete structures.

Since the initial cross-sectional area was identical for all three specimens, it was determined using the following equation:

$$F = \frac{\pi \cdot d_0^2}{4} = \frac{3,1416 \cdot 10^2}{4} = 78,54 \text{ мм}^2 \quad (1.1)$$

The ultimate tensile strength (σ_B) for each specimen was determined using the following equation:

$$\sigma_B = \frac{P_{max}}{F} \quad (1.2)$$

The percentage elongation was calculated using the following equation:

$$\delta = \frac{l-l_0}{l_0} \cdot 100\% \quad (1.3)$$

The average percentage elongation obtained from the test results was 23.165%.

The yield strength (σ_T) was determined from the stress-strain curves obtained during the tensile tests. For the investigated specimens, the yield strength values ranged from 375 to 446 MPa.

The mechanical properties of reinforcing steel used in reinforced concrete structures are evaluated not only on the basis of laboratory test results but also by comparing the obtained data with the requirements of applicable regulatory standards. In the present study, the test results were analyzed in accordance with the requirements of GOST 1497–84, as well as GOST 6727–80 for low-carbon reinforcing steel wire and GOST 10884–94 for thermomechanically strengthened reinforcing steel.

These standards specify the minimum permissible values of ultimate tensile strength, yield strength, percentage elongation, and other mechanical properties of reinforcing steel products. Comparison of the experimentally obtained results with the regulatory requirements makes it possible to objectively assess the quality of the reinforcing steel under investigation and determine its suitability for use in critical reinforced concrete structures.

Table 2

Standard mechanical requirements for 10 mm reinforcing steel according to GOST 34028–2016

Parameter	GOST 34028–2016	Unit	Description
Ultimate tensile strength(σ_B)	≥ 390	MPa	Tensile strength
Yield strength(σ_T)	≥ 350	MPa	Onset of plastic deformation
Relative elongation (δ)	≥ 18	%	Ductility characteristic
Plasticity coefficient σ_B/σ_T	$\geq 1,10$	–	Plasticity reserve coefficient

In the present study, three reinforcing steel specimens with a diameter of $d_0 = 10$ mm were subjected to tensile testing, and the obtained experimental results were compared with the requirements of the applicable regulatory standards (Tables 2–3).

Table 3

Average Results of the Experimental Investigation for Three Specimens

Parameter	Test Result (Average Value)	Unit	Deviation from the Standard
Ultimate tensile strength(σ_B)	485	MPa	+95 MPa
Yield strength(σ_T)	405	MPa	+55 MPa
Relative elongation(δ)	23,165	%	+5,165 %
Strength ratio σ_B/σ_T	1,20	–	+0,10

4. Conclusion

Based on the results of the experimental investigation of the mechanical properties of 10 mm diameter A-III class reinforcing steel, the following main conclusions were drawn:

1. Tensile tests conducted on three reinforcing steel specimens in accordance with the requirements of GOST 1497–84 made it possible to determine the actual values of the main strength and deformation characteristics of the material.
2. The average maximum failure load was 38.073 kN, indicating a sufficiently high tensile load-bearing capacity of the investigated reinforcing steel.
3. The average ultimate tensile strength was 485 MPa, which is 95 MPa higher than the minimum value specified by the applicable standard for the considered class of reinforcing steel.
4. The average yield strength was 405 MPa, which is 55 MPa higher than the minimum specified value. This confirms the ability of the reinforcing steel to withstand significant tensile stresses before the onset of plastic deformation.
5. The average percentage elongation after fracture was 23.165%, exceeding the specified minimum value by 5.165 percentage points. This result indicates sufficient ductility of the reinforcing steel and its ability to undergo deformation without brittle failure.
6. The average ratio of ultimate tensile strength to yield strength was 1.20, which exceeds the minimum specified value of 1.10. This indicates an adequate ductility reserve and favorable behavior of the reinforcing steel under loading.
7. The coefficient of variation of the mechanical properties did not exceed 3.4%, indicating a high degree of uniformity among the tested specimens and consistency of their strength characteristics.
8. Comparison of the experimental results with the requirements of GOST 34028–2016 showed that the investigated 10 mm diameter A-III class reinforcing steel complies with the established regulatory requirements for strength and ductility.
9. The obtained experimental data confirm the suitability of this reinforcing steel for effective use as



longitudinal reinforcement in flexural reinforced concrete structures, including beams subjected to short-term static loading.

10. The experimentally determined mechanical properties of the reinforcing steel can be used in subsequent calculations and analyses of the load-bearing capacity, crack resistance, and deformation behavior of experimental reinforced concrete elements.

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