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Improvement of standards and pulling test methods of reinforcing bars

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Abstract
On the base of analysis of production level and reinforcing bars demand and also checking procedure of its mechanical characteristics there established the necessity of introduction of amendments to the current standard for testing (GOST 12004) by means of cancellation the full relative elongation and test of bars without fracture of samples.
Key words: REINFORCING BAR, MECHANICAL CHARACTERISTICS, TEST METHODS, PULLING, IDENTIFICATION, EXPRESS-CONTROL, STRENGTH CLASS.

Standard for test of reinforcing bars (GOST 12004-81. Reinforcing steel. Tensile test methods.) was brought into action more than 30 years ago. At that moment at the beginning of 1980s reinforcing steel was mainly produced of 400 MPa strength class (class A-III under the GOST 5781) from low alloyed steel of 35GS and 25G2S grades in the hot-rolled condition. These bars combined the required level of strength properties with high elasticity and also were characterized with the presence of yield point (yield plateau on the strain diagram). In consequence of the last the determination of yield point according to the mentioned standard did not required record of strain diagram.

At the present time the situation in the manufacturing and control of properties of bars has changed significantly. The main type of consumed bar became the rolled stock of A500S strength class under DSTU3760 and B500S under DSTU EN 10080 (GOST R 52544 and others), which is manufactured with usage of strengthening technologies - thermomechanical processing (A500S) or cold- deformed (B500S). This rolled stock is produced from less alloy steel. Bars of mentioned classes have lower elastic properties, and what is more important, deformation diagram during test is characterized by smooth transition from macro-elastic strain to the macro- ductile one (fig.1). That is why not physical yield point is determined, but compressional yield point, which complicates the determination of this characteristic as compared with preceding period and requires usage of corresponding equipment.

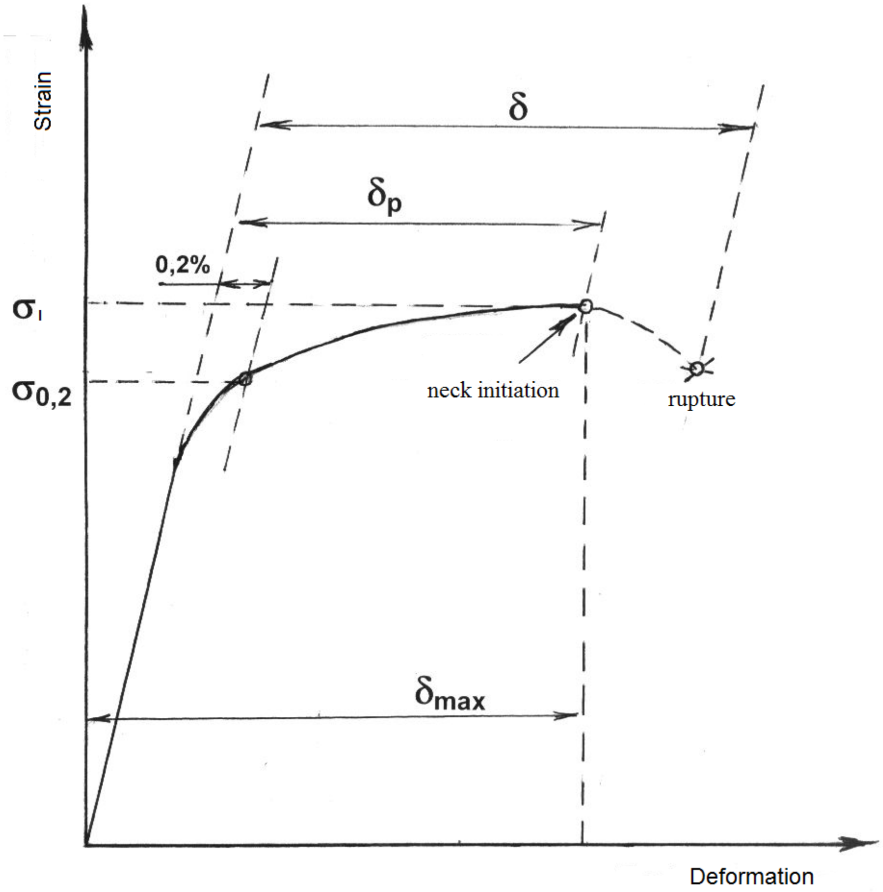

Figure 1. Scheme for determination of regulated properties of reinforcing bars according to the diagram of deformation of samples during monoaxial extension. σ_l – stress limit; $\sigma_{0,2}$ - compressional yield point; δ - full tension set; δ_p - relative proportional elongation; δ_{max} – full elongation under maximum load.

Besides above marked in the acting standards for the bars with normable strength level of 500MPa and higher, on our opinion, there exists an inadmissible one, disagreement in regulatory actions of measuring methods for relative elongation as the main characteristic of plasticity and resistance to breaking of bars [1]. GOST 5781 and GOST 10884 require determination of relative elongation in the point of rupture on the base of five nominal diameters (δ_5) and relatively proportional elongation out-of the point of rupture (δ_r) on the base of 50 or 100 mm. DSTU 3760 requires also determination of full relative elongation under maximum load (δ_{max}).

DIN 488 regulates tenfold relative elongation (δ_{10}) and ASTM A722 regulates also twentyfold one (δ_{20}). Except relative elongations determined on the base divisible by nominal diameter, there also regulated determinations of elongation on the base 100 mm (δ_{100}), and CAN/CSA- G30.18 – on the base 200 mm (δ_{200}). Standards ASTM A615 and ASTM A370 regulate on the bases of 8 and 10 inches ($\delta_{8''}$ и $\delta_{10''}$ respectively). It is obvious that this leads to certain confusion and impossibility of correct correlation of elastic properties of reinforcing bars while as the values of relative elongation without pointing the methods of its determination are given in numerous publications and certificates.

Analysis of informative value of full (δ) and uniform elongation (A_g) as the characteristics of resistance to breaking of bars during exploitation gives reasons to choose the last. Values A_g characterize not just plasticity on this stage of deformation, but also specific metallic resistance to macro-localization of deformation during loading. With macro-localization of deformation there develops nonsteady stage of destruction, occurring during load reduction. The value A_g determines ultimate time of macro plastic deformation higher than yield point, where potential overloads during exploitation without risk of breakage are possible. From the described positions the value δ_u should be left as regulated characteristic of both plasticity and resistance to breaking of bars.

Further it should be marked that the influence of existing methodologies of samples preparation (sketching) and sampling during determination of plasticity characteristics on the value of error is low considered. Suggested methods for sketching application (offset, punching etc) and further sampling with the help of beam compass introduces an error by means of human factor. One may see it demonstrably on the example of usage photo-litho-offset sketching (figure 2). Thickness of layout lines is 0.3…0.5 mm, that is why because of this factor may occur an error in the value of the variable of permanent strain, measured on the base of 50 mm, in 0.5 mm, which will cause 1% error of absolute value of performance level δu. At the time when nominal range of this value for reinforcing bars of B500C – 2,0; A600C - 4,0; A800 and A1000 classes is 2.0%, garbling of effective values of characteristics may be 25…50%.

Complementary errors in determination of plastic characteristics are added by such factors as measuring of residual testing length of samples after rupturing, measured under the signs (punching), located near the biting area of metal by bolt dies of tensile-testing machine and also errors connected with measurement of distances according to the center prick located near the breaking point or at the defects of punching. Also GOST 12004 allows the finite length of the sample after test to measure to a precision of 0.5 mm and full relative elongation after rupture and uniform elongation to calculate with rounding up to 0.5 %. Herein the fractions till 0.25% are dropped and fractions 0.25% and higher are taken as 0.5%. This together is reflected on the accuracy of results.

Figure 2. Layout of reinforcing bars of A240C class with diameter 10 mm with applied sketching after pulling test

In such a way one may consider introduction of changes in corresponding standards on the base of development of new controlling methods of properties during pulling test of reinforcing bars as vital and reasonable.

On the base of above mentioned it is suggested the variant of new test and control method (identification) of properties during pulling of reinforcing bars. For determination of main aspects of mechanical properties: yield point ($R_{p0.2}$), ultimate tensile strength (R_m), full relative elongation under maximum load (δ_{max}) and relative uniform elongation (A_g) the sample should not be carried to failure (rapture). It is enough to load to maximal load (Fm), and after the beginning of load reduction (not more than 0.5%) one should break the test and unload the sample [2]. Previously applied signs of initial sampling length 100 (200) mm will allow to evaluate the deformation of the sample and determine relative uniform elongation (A_g) to high precision. Herein the process of sample sketching itself is simplified, because it is enough to apply only one sampling length (two signs). One should totally refuse from determination of full relative elongation (δ_5) because of idleness of this characteristic for reinforcing bars. Variant of such refusal is already mentioned in GOST R52544 for rolled stock of B500C class and also suggested in the project of interstate standard

"Reinforcing bars for reinforced concrete structures" [3].

New method of identification of properties was checked on the lots of reinforcing bars of B500C class [4]. The methodology included selection, preparation, sketching and pulling tests of site-collected samples of periodic profile, registration of load values and deformation, next evaluation of strength and plasticity characteristics. Pulling is fulfilled in two stages by means of initial pulling of the sample till proof load, which corresponds to normable strain of yield point in 500 N/mm^2, after this the sample is unloaded, the value of residual elongation (Δl1) is measured, further the sample is repeatedly subjected to pulling till maximum load (Fm) with fixation of this value. After this the sample was unloaded, the value of its residual elongation was measured (Δl2), than ultimate resistance (R_m) and relative uniform elongation (A_g), were calculated. Correspondence of rolled stock to B500C class was defined in accordance with the value of residual elongation (Δl1), which should be not more than 0.002 from the initial length, the sample is not subjected to repeated pulling and rolled stock is accepted to be not corresponding to the B500C strength class.

For skilled analysis of B500C identification method the samples of reinforcing bars with diameter 5.5, 8.0 and 11.0 mm were chosen (by two lots of each diameter) with the length by 350 mm. They were pulled on testing machine FP – 100/1. Spacing between the grips of testing machine was 220 mm and on the sample with the help of two signs the sampling length 200 mm was applied. Along the section area and regulated strain of yield point (500 N/mm^2) the required proof load (Ft) was calculated, to which the sample were originally loaded. After that the samples were unloaded permanent strain (Δl1) was measured, which should not exceed 0.40mm.

According to this action the fact of sample correspondence to the requirement of B500C class under yield point was stated. Further the samples were repeatedly loaded to the maximum load (Fm) and these values were fixed. After this the samples were unloaded, the value of its residual elongation (Δl2) was measured, ultimate resistance(R_m) and relative uniform elongatio (A_g) were calculated. The results obtained (see the table) testify that all the samples subjected to the test under new methodology, except the second lot of samples with diameter 8.0 mm, correspond to the requirements of standard for rolling stock of B500C class. In such a way, identification of samples is fulfilled without sketching of samples along the length, without record of load-extension curve and rapture of samples. This allows to reduce the time for test (fulfill express-control) and tests themselves may be fulfilled on the machines of any design.

d, mm	A_n, mm^2	Ft, kN	Δl1, mm	$R_{p0.2}$, N/mm^2	Fm, kN	R_m, N/mm^2	Δl2, mm	A_g, %	Notes
-	-	-	≤ 0.40	≥500	-	≥550	≥4.0	≥2.0	Standard requirements
5.5	23.50	11.75	0,25	satisfying	14.69	625	4.12	2.06	B500C
5.5	23.80	11.90	0,35	satisfying	14.28	600	4.30	2.15	B500C
8.0	50.30	25.15	0,40	satisfying	30.68	610	4.20	2.10	B500C
8.0	50.10	25.05	0,55	failed	-	-	-	-	not B500C by $\sigma_{0,2}$
11.0	95.0	47.50	0,35	satisfying	60.80	640	4.40	2.20	B500C
11.0	94.7	47.35	0,30	satisfying	56.35	595	4.80	2.40	B500C

Conclusions*

1. The necessity of introduction of changes into acting standard for test of reinforcing bars (GOST 12004) on the base of refusal from determination of full relative elongation after rapture (A_5, A_{10} and others) and the usage of methods of express control is shown.
2. Method of identification of reinforcing bars on correspondence to declared strength class without sample rapture is suggested. New method may be recommended for incoming control of mechanical properties of reinforcing bars of A500C, B500C, A600C, A600 – A1000 classes, which will allow to identify it on the correspondence to the

requirements of standards to the production of certain strength class at reduction of general duration of test.

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