EXPERIENCES IN TESTING OF CONCRETE REINFORCEMENT ACCORDING TO EN 10002-1

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Summary: *Construction of Waste Water Treatment Plant (WWTP) is a second component of the Waste Water Collection and Treatment Project in Bihać. WWTP Project included design and construction of complex hydro technical facilities that represent technological parts for waste water treatment. Since majority of facilities of WWTP are designed and constructed as reinforced concrete structures, a special attention was given in quality control of concrete and reinforcement. This paper's focus is the quality control of installed concrete reinforcement at the construction site of WWTP. The aim of the paper is to show, emphasize and share experience with professional community in application and implementation of European norm for concrete reinforcement - EN 10002-1 in Bosnia and Herzegovina.*

Keywords: *EN 10002-1, Testing, Reinforcement Quality Control, Waste Water Treatment Plant*

1. INTRODUCTION

Construction of WWTPs in Bihać is one of the currently most important infrastructure projects in north-west Bosnia and Herzegovina and primarily from the aspect of environment protection and protection of Una river. Considering the benefits of this project, environmental and health protection are primary goals, but other benefits also stand out, like is implementation of European Norms related to the construction works in Bosnia and Herzegovina. The quality control of concrete reinforcement was integral part of overall quality control of reinforced concrete, during the construction of WWTP facilities.

This project is great example of the use of European norms in construction sector in Bosnia and Herzegovina, throughout the whole project, during entire construction, not only of EN 10002-1, but in all other fields of quality control.

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In this paper are demonstrated experiences in quality control of concrete reinforcement according to BAS EN 10002-1, through analysis of tensile testing of concrete reinforcement, as well as all other characteristics obtained through these testing mentioned. This paper also summarizes the procedure of testing and results analysis according EN 10002-1.

2. TENSILE TESTING OF REINFORCEMENT ACCORDING TO EN 10002-1

The tensile test of reinforcement bars involves straining a test piece in tension, generally to fracture, for the purpose of determination of one or more mechanical properties [1]. The tensile test of reinforcement is performed in the way that sample of reinforcement bar of specific diameter is placed into machine, held by jaws at each end of bar, after determining the cross-section area S_o and original gauge length L_o.
Then, a force is applied onto the sample. When the specific force acts on the sample, the reduction in diameter and elongation in length occur.
The sample is treated uniaxial until fracture of bar takes place. When applying the force to the sample, it should be done at the rate shown in the table below:

Table 1. Stress rate [1]

Modulus of elasticity of material E [MPa]	**Stress rate [MPa/s]**	
	min	max
< 150 000	2	20
≥ 150 000	6	60

After sample fracture, final gauge length L_u and minimum diameter S_u are measured. For the purpose of determination of characteristics of reinforcement, following values are considered [6]:

- gauge length (L) - length of cylindrical or prismatic portion of the test piece on which elongation is measured at any moment during the test [m];
- original gauge length (L_o) - gauge length before application of force [m];
- final gauge length (L_u) - gauge length after rupture of the test piece [m];
- elongation - increase in the original gauge length at the end of the test;
- ductility – percentage elongation after fracture (A_{gt}) - permanent elongation of the gauge length after fracture, expressed as the percentage of the original length:

$$A_{gt} = \frac{L_u - L_o}{L_o} \quad [\%] \qquad (1)$$

- extension – increase of the original length at a given moment of the test;

- percentage reduction of area (Z) - maximum change of cross sectional area, which was occurred during the test, expressed as a percentage of the original cross-sectional area:

$$Z = \frac{S_o - S_u}{S_o} \quad [\%] \tag{2}$$

- maximum force (F_m) - the greatest force which the test piece withstand during the test [N];
- stress (σ) - force at any moment during the test divided by the original cross-sectional area (S_o) of the test piece:

$$\sigma = \frac{F}{S_o} \quad [MPa] \tag{3}$$

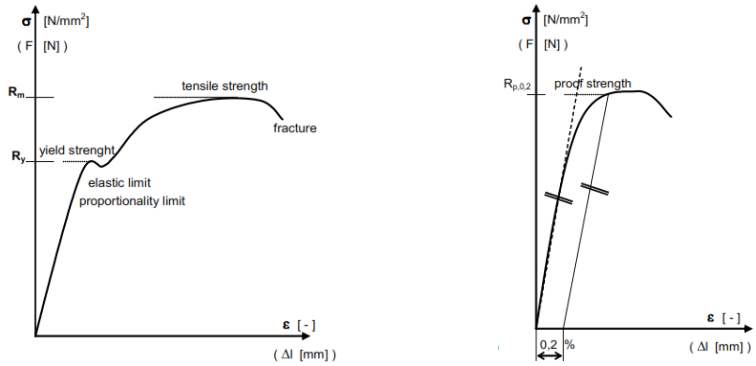
- tensile strength (R_m) - stress, corresponding to the maximum force F_m:

$$R_m = \frac{F_m}{S_o} \quad [MPa] \tag{4}$$

- yield strength (R_y) – when metallic material exhibits a yield phenomenon, a point is reached during the test at which plastic deformation occurs without any increase in the force:

$$R_y = \frac{F_y}{S_o} \quad [MPa] \tag{5}$$

- proof strength (R_p) – stress at which extension is equal to a specified percentage of the gauge length. the symbol used is followed by a suffix giving the prescribed percentage, for example $R_{p,0,2}$.



a) Steel with yield point b) Steel with proof strength $R_{p,0,2}$

Figure 1. Stress-strain diagram [6]

3. REINFORCEMENT STEEL CHARACTERISTICS

In order to meet main requirements, such as weldability and duration, reinforcement steel needs to be of certain chemical composition in corresponding ratio. This chemical composition includes elements shown in the Table 1, the maximum amount of elements allowed to be in the composition.

Table 2.Chemical composition of reinforcement steel [4]

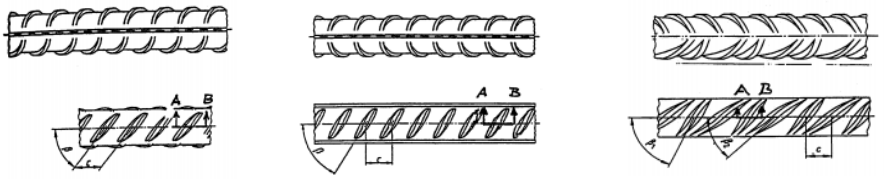
Chemical composition (% per mass)							
Technical class	C	Mg	S	P	N	Cu	Equivalent amount of C
B500B	**0,16-0,22**	**0,40-0,60**	**0,050**	**0,050**	**0,012**	**0,80**	**0,50**

Reinforcement is classified, regarding ductility, into 3 classes A, B and C. This classification is done according to EN 10080, with characteristics and limiting values shown in the Table 2. below.

Table 3. Required reinforcement steel characteristics according to EN10080 [2]

Class and label of steel	**B500A (1.0438)**		**B500B (1.0439)**		**B450C (1.04..)**
Shape of product	Coiled	Rods/bars	Coiled	Rods/bars	Coiled
Nominal diameter d [mm]	4-16	6-40	6-16	6-40	6-16
Yield strength Re [MPa]	≥500		≥500		≥450
Ratio of tensile strength and yield strength R_m/R_e	≥1,05[1)]		≥1,08		≥1,15 ≤1,35
Total elongation A_{gt} [%]	≥2,50[2)]		≥5,00		≥7,50
[1)] $R_m/R_e \geq 1,03$ for d=4,0 to 5,0 mm					
[2)] $A_{gt} \geq 2\%$ for d=4,0 to 5,0 mm					

Ductility classes can be also distinguished by the rib number and position on the reinforcement bars (*Figure 1*). Reinforcement steel class A has three rows of transverse ribs, while reinforcement steel class B has two rows. Reinforcement steel class C differs from classes A and B in the angle of rib position.



Class B500A Class B500B Class B450C

Figure 2. Reinforcement appearance according to ductility classes [5]

Generally, when discussing labelling of reinforcement steel, according to EN 10027-1- Designation systems for steels – Part 1: Steel names, first capital letter B represents the label of steels for reinforcing concrete, followed by number 500 or 450, which represents characteristic yield strength in MPa for the smallest dimensional range.
Since 22 out of 25 facilities of WWTP were reinforced concrete structures, a careful attention was directed to quality control of installed reinforcement, since the amount of reinforcement placed into structures exceeded 700 000 kg. All reinforced concrete facilities are designed with the reinforcement class B500B, which was enough to ensure structural stability and durability. Diameters of bars delivered to the site and placed into concrete elements were of Ø8, Ø10, Ø12, Ø14, Ø16, Ø19, Ø20, Ø22 and Ø25 mm respectively, as well as reinforcing mashes Q335.

Figure 3. Reinforcement installation for the base slab of Activated Sludge Tank

4. TENSILE TEST RESULTS ANALYSIS OF REINFORCEMENT

In this paper, tensile testing and analysis of reinforcement for WWTP facilities are presented. As mentioned earlier, the reinforcement was made of the reinforcing steel

ribbed bars with characteristic yield stress of 500 N/mm^2. All reinforcement was clean and free from pit corrosion, loose rust, mill scale, paint, oil, grease, adhering earth, or any other material that may impair the bond between the concrete and the reinforcement or that could may cause corrosion of the reinforcement or may be detrimental to the quality of the concrete. Storage of reinforcement was on racks or supports clear of the ground. Different types and sizes of reinforcement were kept separate. Reinforcement test samples were taken continuously during the construction, complying with quality control programme.

Regarding test results, as displayed earlier in the Table 3, minimum limiting value for the B500B reinforcement grade is 500MPa for yield strength. Required tensile strength, corresponding to obtained yield strength, is given by the ratio of tensile strength and yield strength R_m/ R_e to be minimum 1,08. Total elongation should be equal to or greater than 5%. The test result analysis of tensile testing of reinforcement is presented in following charts.

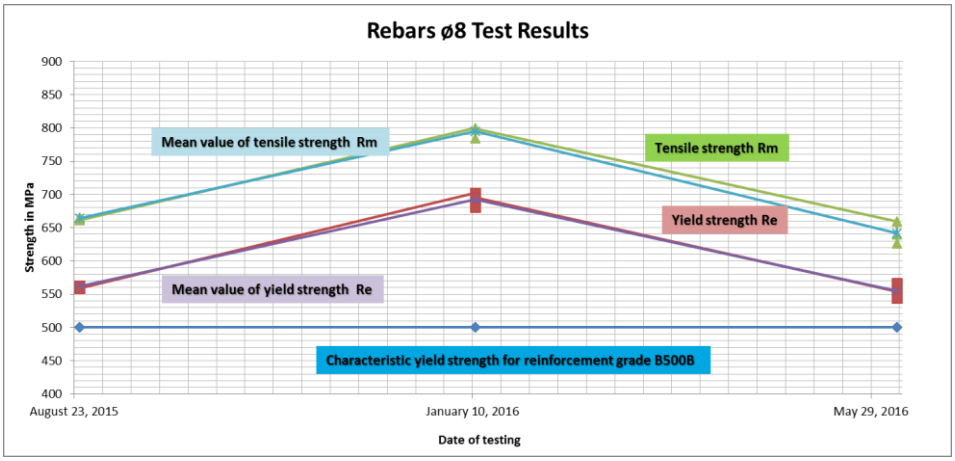
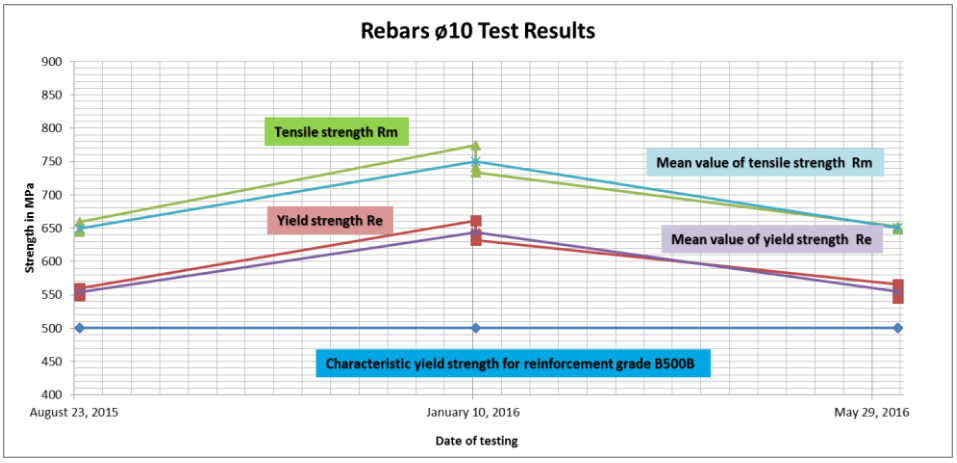


Figure 4. Test results for Ø8



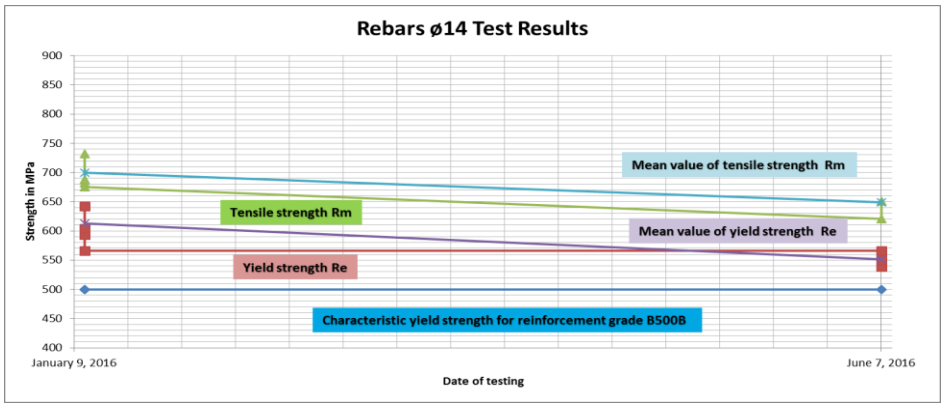


Figure 5. Test results for Ø10
Figure 6. Test results for Ø14
Figure 7. Test results for Ø16

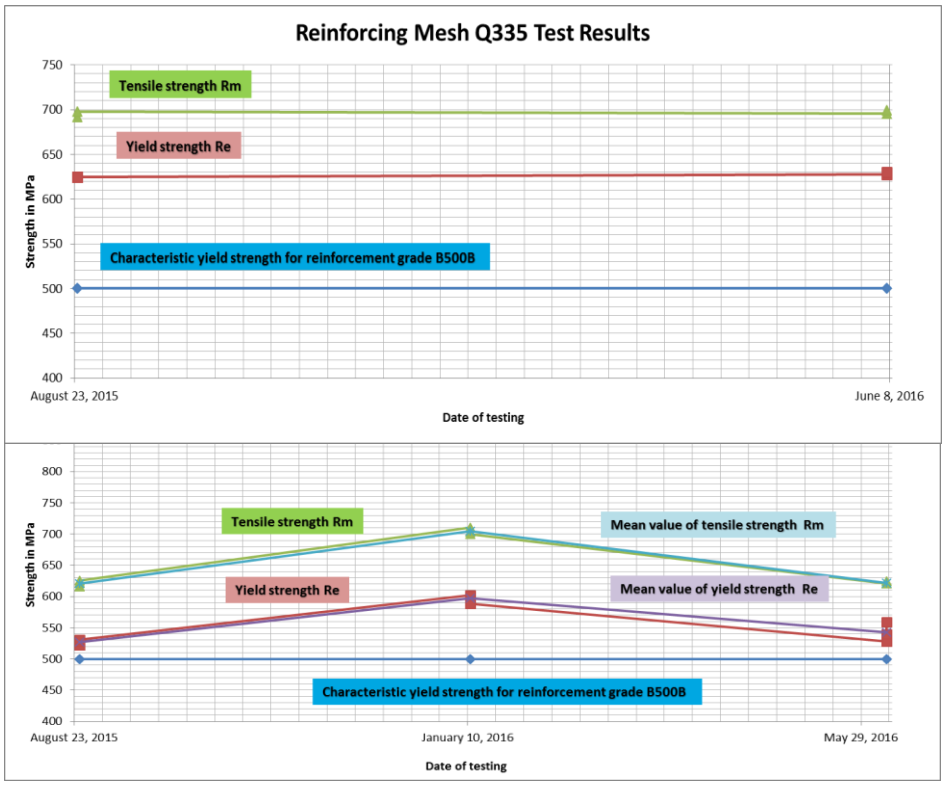


Figure 8. Test results for reinforcing mesh Q335

5. CONCLUSION

This paper analyses the results obtained by tensile testing of reinforcement grade B500B during construction of Waste Water Treatment Plant facilities in Bihać, and following conclusions can be drawn:

- Yield strength values for bars Ø8, Ø10, Ø14, Ø16 mm and reinforcing mashes Q335 meet the required limiting value for reinforcement B500B, which is $\geq$ 500 MPa;
- Yield strength test results values for bars Ø19, Ø20, Ø22 and Ø25, which were not shown by the graph, (since only one test sample was required according to quality control programme), also meet the required limiting value for reinforcement B500B, which is $\geq$ 500 MPa;
- Shear strength value of the weld for reinforcing mesh Q335, tested on August 24, 2015 are 12,6 and 13,2 kN (for two samples), which is above the limited value of 6,3 kN;
- Shear strength value of the weld for reinforcing mesh Q335, tested on June 6, 2016 are 12,8 and 13,6 kN (for two samples), which is above the limited value of 6,3 kN;
- Tensile strength for all rebars satisfies the R_m/ R_e ratio, since all ratio values are above the limiting value of 1,08;
- Total elongation for all test samples more than satisfies the required value of 5%.
- As it can be concluded from test result analysis above, all tested reinforcement samples for all reinforcing bars and mashes comply with EN 10002-1 in all aspects specified for testing.

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ИСКУСТВА ИСПИТИВАЊА БЕТОНСКЕ АРМАТУРЕ У СКЛАДУ СА EN 10002-1

Резиме: *Изградња Постројења за пречишћавање отпадних вода (ППОВ) је једна од компонента Пројекта за прикупљање и третман отпадних вода у Бихаћу. Пројекат ППОВ-а укључује пројектовање и изградњу комплекса хидротехничких објеката који представљају технолошке дијелове постројења за третман отпадних вода. Будући да је конструкција већине објеката ППОВ-а пројектована*

и изграђена од армираног бетона, посебна пажња је посвећена контроли квалитета бетона и арматуре. Фокус овог рада је контрола квалитета уграђене бетонске арматуре у објекте ППОВ-а. Циљ овог рада је да се презентирају, нагласе и подијеле искуства са стручном јавношћу у примјени и имплементацији Европске норме за бетонску арматуру - EN 10002-1 која су стечена у Босни и Херцеговини.

Кључне речи: *BAS EN 10002-1, Тестирање, Контрола квалитете арматуре, Постројење за пречишћавање отпадних вода*