The assessment of the radio tower bearing capacity during the installation of some additional equipment

Alexander P Mashtakov and Rustam R Khakimzyanov
Russian University of Transport (MIIT), B. 9, 9 Obraztsova St., Moscow, 127994, Russia

E-mail: khakrr@yandex.ru

Abstract. The article presents the assessment data that explain how the defects impact on the bearing capacity of radio tower pylons and stress and strain state of the pylons. The obtained results raise the possibility of replacing the equipment set on the radio towers with the additional equipment, including the one for solar radiation regeneration.

At present time a number of transport infrastructure facilities are losing their direct purpose. First of all, this is due to the development of machines and the emergence of new technologies that involve fundamentally new solutions to the existing problems. These lead to the necessity to stop the operation of the facilities or to use them in a new way. To such facilities belong the pylons of radio relay communication towers of 318T and 318RU projects, which are in operation on the railways (figure 1). They are widely used as antenna and feeder devices for the cellular transmission and more often as a direct telecommunication equipment [1]. At the same time, in contrast to the cellular transmission pylons (RMG), these projects of radio relay communication towers have a number of advantages and a high design latitude (up to 85.5 m). The design solution of these structures has a latticed square structure, which takes form of a dimensional frustrum.

Figure 1. The radio relay communication tower of Project 3183T.
Taking into consideration a vast area, occupied by the unused design process equipment at the moment, it was proposed to use the towers of this type as the pylons for the installation of the electric energy storage equipment [2]. It is planned to install the equipment for solar radiation regeneration.

When inspecting the state of these structures, located on the territory of the Volga railway, the following work was performed: the maintenance check with the use of instrumental measurements, the identification of damages and defects, on the basis of which the verification calculations were done and the operational state was assessed.

In the Volga and Northern Caucasus federal districts, the operational state of the pylons of the radio relay communication towers for Projects 3183T and 3183RU was thoroughly inspected and a number of systematically detected damages and defects, as well as unique ones which were peculiar to specific objects.

As an example, we present the results of a detailed inspection of the radio relay tower at the Bezymyannaya station in the Saratov region. The height of this pylon corresponds to the design and is 85.5 m. The distance between the central supporting foundations of the belts is 10.25 m. It was put into operation in 1976. The weight of the pylon is 51.8 t.

The foundations are four-step concrete poles with the size of 1.2 x 1.2 m, separately located in the above-ground part. The attachment point of the supporting flange on the foundation is made by embedding the anchor bolts in the foundation, which in turn are attached to the space frame from the corners. During the inspection of the pylons, the strength of concrete was determined. As a result, in the above-ground part the concrete strength of Foundation 1 was 205 kg/cm², the concrete strength of Foundation 2 was 233 kg/cm², the concrete strength of Foundation 3 was 184 kg/cm², the concrete strength of Foundation 4 was 244 kg/cm², while the concrete brand M-150 was chosen for this project. The orientation of the foundations and the results of checking the diagonals are shown in figure 2. The discrepancy between the lengths of the diagonals did not exceed the permissible and amounted to 10 mm, figure 2.

![Figure 2](image_url)

**Figure 2.** The dimensions of the aerial part of the foundations and relative elevations from two mutually perpendicular sides of the RRL support at Bezymyannaya station.
The spatial bar support system was made in the form of two bad trusses connected by struts and cross-shaped links. The inspection was performed with the help of measurement works and visual inspection of each element and joint. The trusses were made of the variable height, with a girder slope of 1/20. In general, the pylon is a frustrum of pyramid with a through latticed structure. The elements are fastened with the bolts of normal accuracy. The trusses have 17 panels and a cross-shaped grid. All bars connections are bolted. The belts are joined on the flanges in five lower panels with the help of ten bolts, and in four middle panels - with eight bolts. In eight upper panels, the flanges in the belts are jointed with six bolts. In the lower flanges, the bolts have the diameter of 30 mm; in the upper flanges, the diameter of the bolts is 27 mm. The flange holes have the diameter of 3 mm bigger than the diameter of the bolts. The belts are made of pipes of the variable diameter: from 273 mm in the five lower panels, 219 mm in the four middle panels and 159 mm in the eight upper panels. The pylon is fixed to the anchor bolts with the diameter of 65 mm on the supporting flanges.

The equipment installed on the pylon is shown in table 1.

### Table 1. The list of antennas installed on the RRL pylon (the Bezymyannaya station).

| Antenna type                        | Installation mark, m | Quantity | Comments         |
|-------------------------------------|----------------------|----------|------------------|
| Parabolic D = 1.2 m                 | 42.3                 | 1        |                  |
| Circular antenna D = 1.2 m          | 57.5                 | 1        |                  |
| Panel antennas                      | 61.25                | 4        |                  |
| Circular antenna D = 2.4 m          | 61.25                | 1        | Cell communication |
| Panel antennas                      | 76.25                | 3        | Cell communication |
| Circular antenna D = 1.2 m          | 76.25                | 2        |                  |
| Panel antennas                      | 77.0                 | 2        | Cell communication |
| Circular parabolic antenna D = 3 m  | 85.5                 | 1        | Siemens          |

Having done the visual inspection, the forces in the elements of the pylon bar system were determined.

The determination of internal forces in the pylon elements was carried out like in the dimensional latticed bar system on the computing complex Mirage [3]. The calculation took into account the loads according to the regulations [4] and [5]. The calculation resulted in the values of maximum compression and tension forces in the belts, braces and struts. The numerical values are presented in table 2.

The verification for the maximum slenderness according to the regulation [5] showed that in all cases the designed slenderness of the compressed struts exceeded the maximum slenderness:

- for the struts from the bend of № 10 (d = 10 mm) - the designed slenderness is 212 MPa when the limit one is 120 MPa.
- for the struts from the bend of № 7,5 (d = 6 mm) - the calculated slenderness is 226 MPa when the limit one is 120 MPa.

The value of the maximum slenderness was determined according to the regulation [6].

Further calculations were carried out for the selected bars when they were hinged and fixed firmly at the ends.

The calculation of bolted joints of the struts was carried out on the basis of the shear of the maximum longitudinal force. The calculation of bolted joints in the belt flanges was carried out on the basis of the shear of the wind load, and the calculation of the tension under eccentric loading - on the basis of the shear of the tension force in the belt. The value of force was determined due to the results of the pylon static calculation to the load action under the own pylon weight, ice and wind loads. The calculated resistances to the shear and tension of the bolt type 4.8 were assumed to be equal to 160 MPa, according to the regulation [4]. The calculation results are presented in table 2.
Since the soil conditions had not been determined, the calculation of the concrete under the metal base plate was carried out as a centrally compressed concrete element.

A compression force equals to \( NP = 477200 \) H was transmitted from the belts to the foundation. The verification results of the anchor bolt defects due to the strength and endurance conditions were also taken into account [7].

The concrete strength determined during the inspection was 184 kg/cm\(^2\) (18.4 MPa). The dimensions of the metal base plate in the plan are 500x500 mm, so the voltage \( \sigma \) under the plate is 1908800 Pa (1.9 MPa).

Thus, the obtained value of the amount of stresses under the plate does not exceed the concrete strength and, as a result, the concrete strength is provided.

The recommendations for the elimination of identified defects are specific for each inspected facility. The proposed methods meet regulatory requirements [8].

Strengthening of the metal bar systems should be performed, as a rule, only in case of significant corrosion wear or significant local damage, as well as in case of the increase in operating loads. Most often, strengthening is done without unloading the structures by means of increasing the cross-sectional area of the elements. In exceptional circumstances, it is possible to change the initial designed scheme.

| Table 2. Maximum force in the pylon elements with the verification of the bolted joints. |
|---------------------------------------------------------------|
| Profile  | № joint | Force, H | Min designed diameter of a bolt, mm | Number of bolts, items | Diameter of a bolt according to the design, mm |
|----------|----------|----------|------------------------------------|------------------------|---------------------------------------------|
| Ug 100x100x8 | 122 | 48900 | 11 | 10 | 20 |
| Ug 75x75x6 | 126 | 27200 | 8.5 | 8 | 20 |
| TrD - 219/8 | 198 | 20400 | 7.24 | 6 | 20 |
| The calculation for the shear in the struts |
| TrD - 273/10 | 3 | 30924 | 4.96 | | 30 |
| TrD - 219/8 | 28 | 20112 | 4.47 | | 30 |
| TrD - 159/7 | 72 | 13737 | 4.26 | | 30 |
| The calculation for the shear in the belts |
| TrD - 273/10 | 258 | 250200 | 16.08 | | 30 |
| TrD - 219/8 | 264 | 131300 | 13.03 | | 30 |
| TrD - 159/7 | 268 | 54100 | 9.66 | | 30 |
| The calculation for the tension with bending in the belts |

The detailed inspection of the radio relay communication towers with the further calculations for their strength and stability showed that some structural elements are subjected to loads that exceed the design limits. However, the design solution of the inspected towers of the radio relay lines allows the elastic loss of stability in the compressed struts, the so-called systems with disconnecting relations. At the same time, the loss of stability beyond the elastic deformations causes an irreversible curvature, which requires some measures to restore the design position of the grid elements in the tower. Therefore, it is possible to replace the equipment, installed on the towers, to locate the equipment for solar radiation regeneration, as well as other additional equipment, only after carrying out the detailed calculations for each specific tower [9].

References
[1] Grishunin V E, Dol D V, Kuznetsov I M and Mashtakov A P 2014 The dimensional elastic operation of the bar system of radio and TV towers (Saratov: publishing center Nauka)
[2] Sinitsyn S A 2019 The information approach to the design of technical facilities of transport mechanical engineering on the basis of CAD Modern issues of railway transport 15 13-21
[3] Levchuk T V 2013 Modern packages of applied programs in engineering and scientific activity *History and prospects of the transport development in the north of Russia* 1 196-200

[4] Rules and regulations 20.13330.2011 *Loads and impacts Updated version of SNiP 2.01.07-85* (Moscow)

[5] Rules and regulations 16.13330.2011 *Steel structures Updated version of SNiP II-23-81* with Regulatory change N 1 (Moscow)

[6] RD 34.21.306-96 *Procedural Guidelines for Inspection of the Dynamic State of Structural Elements of Structures and Equipment Foundations at Facilities of the Energy Industry* (approved by the Order of the UES of Russia RAO dated back to June 24.1996)

[7] Mashtakov A P and Khakimzyanov R R Analysis of the anchor bolts operation of the dimensional structures with rigid fastening of belts in the foundation *Materials of the scientific and practical conference No. 1 Mechanics and mechanical engineering. Science and practice* (Saint Petersburg: Saint Petersburg branch of the scientific and research center “MechanicalEngineering”) pp 31-4

[8] Mashtakov A P, Mickiewicz V G and Khakimzyanov R R 2018 *Mechanics* (Moscow: MIIT) p 243

[9] Pavlov P I, Bedilo P S, Makarov S A and Khakimzyanov R R 2018 *Designing the drive of transporting machines* (Limited Liability Company "Amirit") p 165