The antenna mast reconstruction structure’s technical support

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Abstract. The article is devoted to technical support of engineering surveys and design during the structures’ construction. Technical support aims to develop and implement the new research methods to obtain the most accurate and reliable data. The author considers the tower of NSC JSC as an example for the possibility of installing the additional equipment for the BS 66487 “New Dzheguta” base station. The design indicators’ determination was carried out using the Selena computer program, which made it possible to get the structure’s actual performance in a short time, excluding the fairly old methods of examining the construction sites, to facilitate the work and reduce the time spent on diagnosis at the same time.

Introduction
In recent years, in connection with the ever-increasing volumes of technically complex structures’ construction, the relevance of such activity areas as technical support of the structural reconstruction project has also grown. In contrast to the usual technical supervision, the task of which is to monitor the prospectors’ work in the field and in the laboratory, such a direction as scientific and technical support is involved, in particular, in the development and implementation of new research methods in order to obtain the most accurate and reliable data that would allow not only to be sure of the structure’s uninterrupted operation reliability, but also to reduce costs in the work performance.

Materials and methods
Significant experience in the production and operation of antenna mast structures in Russia and abroad testifies to their sufficient operational reliability, which was facilitated by numerous research and design work in the direction of improving changes in the design parameters and their manufacturing technology [2, 7, 8].

The greatest contribution to the calculation theory and structures design of this type was made by Davydov I.I., Krasnoshchekov Yu.V., Gureev D.M., Doronin S.V. In recent years, much attention to the mast structures’ technical diagnosis study has been given in the works of Kulyabko V.V., Bakhtin V.F., Loktev A.A. [6, 9].

Many publications, to one degree or another, concern the analysis and assessment of the building structures’ state. The ideological and substantive side of the research direction in question intersects with a number of scientific works, for example, in the article “Monitoring changes in the stress-strain state of of buildings and structures based on the spatial coordinate models’ FEM analysis” by Korgin A.V. and Ranov I.I., as well as in the article “Monitoring of buildings and structures” by Petrov A.V.
and Eremeev A.I., the question of introducing modern software systems for assessing the state of a structure arises [3, 5, 10].

Technical inspection of antenna mast structures is one of the most critical processes when working with objects, and is carried out in order to identify the degree of physical wear, defects, and to determine the operational qualities of the structures; predicting their future behavior.

Technical inspection is carried out if it is necessary to determine the residual bearing capacity and the actual state of the antenna mast structures; when installing additional equipment; in assessing the construction mechanisms of antenna mast structures in order to ensure the structure’s safe operation.

The composition of the antenna mast structures’ preliminary technical examination includes:

1) geodetic control:
   — checking the support shaft metal structures’ verticality;
   — foundation elevation control;

2) visual measurement control:
   — inspection of the antenna mast structure’s bearing metal structures (defects in structural elements, completeness and reliability of mounting joints, condition of the anti-corrosion coating, registration of defects and damage);
   — measuring control (verification of sections and support nodes with the design data, in the absence of field measurements, determination of the closed sections’ thickness by the ultrasonic method, verification of the concrete structures’ strength by non-destructive methods; tension determination in nonrotating ropes);

3) data collection for calculating the bearing capacity:
   — analysis of the survey results, design and operational documentation;
   — collection of existing and planned loads on the antenna thrust.

For example, the NSC JSC tower was considered for the possibility of installing the additional equipment of PJSC VimpelCom of the BS 66487 “New Dzheguta” base station. The barrel of the tower H = 25.2 m is a spatial rod structure in the form of a tetrahedral truncated pyramid. The basic dimensions of the tower are: - at around 0,000 m - 1.9 m; - at the mark of +25,200 m - 0.95 m. Structurally, the tower consists of 3 pyramidal sections. The adjacent sections belts’ connections are made by welding using overlays. Belts, braces and struts are made of equal corners. The mounting connections of the lattice elements to the tower belts and to each other are made in welding. A vertical ladder located inside the tower barrel is provided for lifting onto the thrust.

The spatial rod system was adopted as the design scheme of the AMS (Figure 1).
Verification calculation was performed in accordance with the requirements of current applicable norms and rules, including:
- BC 16.13330.2017 Steel structures. Updated edition of SNiP II-23-81 *;
- BC 22.13330.2016 SNiP 2.02.01-83 * “Foundations of buildings and structures”;
- BC 63.13330.2012 SNiP 52-01-2003 “Concrete and reinforced concrete structures. Basic provisions”;
- BC 131.13330.2012 SNiP 23-01-99 * “Construction Climatology”; BC 20.13330.2016 “Loads and impacts”, the updated version of SNiP 2.01.07-85 *; BC 14.13330.2018 SNiP II-7-81 * “Construction in seismic areas”.

The tower structures are designed according to the method of the design loads’ limit states, including:
- the load from the dead AMS weight (Figure 2), technological platforms, antenna-feeder equipment;
- wind load on the support structures and antenna-feeder equipment (the main type of wind load, resonant vortex excitation);
- ice load.

![Figure 2. Static load 1 (dead weight + equipment)](image)
Verification calculation was performed using SELENA 2019 PC, a specialized software package that implements the finite element method (Figure 3).

Due to the lack of design documentation and in accordance with the requirements of clause 18.2.4 of BC 16.13330.2017, the bearing capacity of the tower elements was checked with a design resistance to tensile, compression, and bending of the 210 MPa yield strength.

\[ \text{Figure 3. Combination graph (1 – the first static load (dead weight + equipment); 2 – the second static load (wind pressure under 0'); 3 – the third static load (wind pressure under 45'); 4 – the fourth static load (temperature effect -25°C); 5 – the fifth static load (temperature effect +36°C); 6 – the sixth static load (ice load); 1w – the second static load pulsation; 2w – the third static load wind pulsation; 1m – seismic impact)} \]

The bearing capacity of the antenna mast metal structures for the I group of limiting states is not provided (Figure 4). Stresses in the belts’ load-bearing elements vary from the mark +0,000, up to the mark +5,600 m and from the mark +11.06 up to the mark +18,100 m of the bracing beam from the mark +2,200 up to the mark +12,000 m, with the brace pieces from the mark +0,000 up to the mark +2,200 m and from the mark +11.060 up to the mark +18,100 m, in the metal structure of the site at the mark +25,200 m exceed the maximum permissible values (k=1.85 – is the belts’ bearing capacity utilization coefficient; k=2.72 – is the struts’ bearing capacity utilization coefficient; k=1.51 – is the braces’ bearing capacity utilization coefficient; k=2.30 – is the metal structure’s bearing capacity utilization coefficient on the site).
Figure 4. Checking sections of tower elements
(red color indicates elements that have not passed the test)

The antenna mast metal structures’ bearing capacity for the II group of limiting states is provided. The relative deviation of the tower meets the requirements of the code 17.7 of BC 16.13330.2017 (does not exceed 1/100 of the height) (Figure 5). The estimated deviation of the tower at +25.200 was 154 mm.

The bearing capacity of the anchor bolts is not provided. The force in the bolts exceeds the maximum permissible values (k=1.20 – is the anchor joint’s bearing capacity utilization coefficient).

The bearing capacity of the underground part is provided. The draft of the foundation slab was 0.56 mm. The plate roll along the axis X amounted to 0.00854, the plate roll along the axis Y amounted to 0 (Figure 6).
Figure 5. The maximum deviation of the antenna mount

Figure 6. Foundation slab
(lengthwise Y = 3,9 m, widthwise X = 3,5 m, the plate thickness = 1 m, reduced load: My = 925 kN*m; Mx= 0 kN*m)
Sole pressure \( P = 28.45 \) kPa does not exceed the design resistance of 1 layer, equal to 320.56 kPa. The antenna mast structure underground part’s reinforcement is not required.

**Research results**

The design organizations specializing in the development of reconstruction projects for these structures perform, in most cases, the simplified calculations [1, 4], not supported by the high-quality engineering calculations.

In this regard, there is a need to develop the technical solutions that could be applied with high reliability and engineering feasibility based on the results of calculating the bearing capacity and analysis of the calculation results from the existing antenna-feeder devices’ loads, the planned additional equipment and the newly mounted structural elements.

The AMS structures’ bearing capacity is not provided. Installation of antenna-feeder equipment in addition to the existing equipment is allowed with the reinforcement belts’ implementation from the from the mark +0,000, up to the mark +5,600 m and from the mark +11.06 up to the mark +18,100 m of the bracing beam from the mark +2,200 up to the mark +12,000 m, with the brace pieces from the mark +0,000 up to the mark +2,200 m and from the mark +11.060 up to the mark +18,100 m, in the metal structure of the site at the mark +25,200 m, as well as the anchor connection reinforcement.

Strengthening of the belts, bracing beams and brace pieces of the tower is performed by increasing the cross-sectional area of the L-bars. Anchor joints are reinforced by the addition of supplementary foundation bolts.

**Summary**

As a result of the antenna mast structure diagnostics using this software package, we can get the actual performance of the structure in a short time, facilitate the work, reduce the time spent on diagnosis, excluding the fairly old methods of surveying the construction sites.

**References**

[1] Shchutsky V L, Korobkin A P, Shevchenko A S, Stelmakh S A 2017 The study of the work of conical supports of power lines as racks for antenna tower superstructures *Science of Science* 4, Information on [http://naukovedenie.ru/PDF/43TVN417.pdf](http://naukovedenie.ru/PDF/43TVN417.pdf)

[2] Fil O A, Rusinov P P 2016 Assessment of changes in organizational and technological characteristics during the construction of residential buildings in cramped conditions *Engineering Bulletin of the Don* 2, Information on [ivdon.ru/ru/magazine/archive/n2y2016/3632](http://ivdon.ru/ru/magazine/archive/n2y2016/3632)

[3] Fil O A, Terentyev V A 2017 An innovative method of analyzing the actual cost of work *IOP Conference Series: Materials Science and Engineering* 262 (1), iopscience.iop.org/article/10.1088/1757-899X/262/1/012076/pdf

[4] Shilov A V 2016 Innovative methods for reinforcing precast concrete structures with carbon fiber nets *Engineering Herald of the Don* 1, Information on [ivdon.ru/ru/magazine/archive/n1y2016/3572](http://ivdon.ru/ru/magazine/archive/n1y2016/3572)

[5] Fil O A, Kliuchnikova O V 2019 On studying the R&D support and the bridge structure monitoring *IOP Conference Series: Materials Science and Engineering* 698. doi:10.1088/1757-899X/698/7/077004

[6] Bakhtin V F, Chernikov I Yu, Loktev A A 2012 Calculation of the dynamic impact of the mast of a cellular communication system and the floor slab on which it relies *MSCEU Herald* 8 66-75.

[7] Keeling Richard P, Ric Underhile, Andrew F Wall 2007 Horizontal and Vertical structures: The dynamics of organization in higher education *Liberal Education* 93(4) 22-31.

[8] Pobegaylov O, Fil O, Tchyoubka P, A Ai-Shamiru 2019 The strategy of production targets and the environmental planning in construction *E3S Web of Conferences* 91. doi.org/10.1051/e3sconf/20199108010
[9] Davydov I I, Chaban V P 2007 Features of the diagnosis of steel structures of masts and towers for mobile cellular communications *Theoretical foundations of construction* **15** 117-124.

[10] Samigullina A G 2017 The need to develop a model of an expert system for diagnosing the technical condition of building structures *Young scientist* **51** (185) 88-90.