# Natural resource management in the engineering protection of puppet theater structures from external impacts

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**Abstract.** The paper considers the management of natural resources with their negative impact on the public building structure. Recommendations for the engineering protection of the object under consideration from atmospheric precipitation that damages the building structure have been developed. The paper considers the test report of the load-bearing structures of the puppet theater building. Based on the performed surveys of the technical condition, it was found that the operational safety and durability of the building structure do not meet the current regulatory documents requirements. Based on the instrumental survey of the load-bearing structure of the building, conclusions about the required conditions for ensuring the safety of operation were made. Also the proposals for the further normal operation of the building were made. Measures to improve the technical condition of the tested elements of building structures have been developed. The following is recommended: to ensure the fulfillment of technical conditions for water-bearing communications; make a waterproof coating of sidewalks; maintain the required temperature and humidity conditions necessary for the maintenance of premises, basements and technical undergrounds; modernize the wastewater collection system from the re-covering of the open gallery; perform weather protection of the joints of steel beams of the gallery ceiling with columns; perform corrosion protection of steel structures; perform a number of works to protect the outer walls of the building structure and the technical base from moisture; to constantly monitor the condition of the building.

## 1 Introduction

Any structure during operation is subjected to the intense influence of external and internal negative factors: power loads, adverse climatic conditions, physical, mechanical, chemical influences [1, 2]. They contribute to a gradual decrease in strength characteristics [3-5]. To slow down the rate of destructive processes, it is necessary to regularly analyze buildings and structures, record the current state and carry out adequate repair and restoration measures [6, 7].

Comprehensive examination of the object consists of four basic stages [8, 9].

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1. The study of information about the object, the land plot and the surrounding area: design and technical documentation, engineering and geological surveys, topographic surveys, the results of previous surveys.

2. Visual inspection and measurement work with photo fixation of visible defects and deformations.

3. Instrumental research by methods of destructive and non-destructive testing. Laboratory analyzes and testing of test samples of the material.

4. Processing of the received data, execution of a technical report.

## 2 Materials and Methods

The object of visual and instrumental examination is the load-bearing structures of the building of the Voronezh State Puppet Theater named after V.A. Volkhovsky, located at the address: Voronezh, Prospekt Revolyutsii, 50 (Fig. 1).

The walls of the building are finished with plaster, plasterboard sheets, ceramic tiles, decorative tiles made of natural stone. Ceiling is finished by whitewash, putty on prefabricated elements [10, 11]. There are plaster layer or decorative gypsum tiles on monolithic and stone structures, suspended and hemmed ceilings in the administrative part of the building, stretch ceilings in the winter garden [12, 13].

The building is equipped with engineering systems: water supply, sewerage, heating, ventilation, fire alarm and other low-valtage systems. Steel water and gas pipes and plastic pipes were used for heating the building. Convectors, cast-iron radiators and registers made of smooth pipes are used as heating devices [14- 16].

In the process of work, the following were carried out: examination of elements of non-existent structures of the building with the identification and fixation of the main defects, control and instrumental measurements, non-destructive testing of concrete in order to determine the strength and uniformity, non-destructive testing of masonry materials of load-bearing walls [17, 18], laboratory tests of masonry bricks for compressive and bending strength, non-destructive testing of the strength of the material of steel structures, laboratory testing of steel samples taken from the most stressed elements of steel structures, control of the reinforcement scheme of load-bearing reinforced concrete structures of the coating and ceilings, assessment of the technical condition of the load-bearing structures of the building, work on measurements of structures in the amount necessary to assess the technical condition and to carry out drawings of plans and sections of the building [19, 20].

**Fig. 1.** General view of the surveyed building.

## 3 Results

Based on the report of the instrumental survey of the building's load-bearing structures, a conclusion on the operational reliability was made, and recommendations for further normal operation were given.

During the survey of wall structures, the following main defects were identified:
- sedimentary cracks in the facade walls of the main building and outbuildings;
- violation of the fastening of decorative tiles on the facade, the danger of falling off;
- lack of structural design of expansion joints between parts of the building;
- damage to the masonry along the interface line, intensive soaking of the decorative elements of the facades as a result of a malfunction of the ebb, the risk of fragments of the plaster layer and masonry falling off;
- defrosting in the walls basement as a result of moistening by an unorganized spillway from the roof, water discharge from the internal drainage system to the blind area, moistening and sedimentation of the base;
- defrosting and destruction of the cornice part of the wall.

During the survey of load-bearing structures, it was found that structural elements and their interfaces have defects and damage that reduce strength and operational reliability. Identified defects were acquired at the stage of construction of the building and during its operation.

As example of defects is shown in Fig. 2 (Technical report on the results of engineering and geological surveys. Object: "Voronezh State Puppet Theatre named after V.A. Volkhovsky". Voronezh region, Voronezh, Prospekt Revolyutsii, 50 Arch. No. 24-10-2019):
- falling away of the plaster layer and decorative elements fragments;
- cracking of cornices, falling off of cornices modillions, as a result of design flaws in their fastening.

Another example of defects is inclined cracks in the outer and inner walls, caused by uneven settlement of foundations, with an opening width of up to 6.0 mm (Fig. 3).

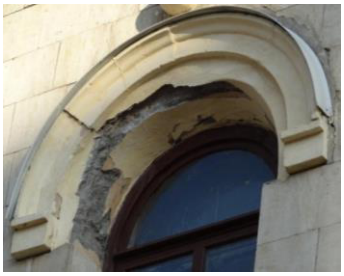

**Fig. 2**. View of defrosting and falling of decorative elements of window frames and masonry.

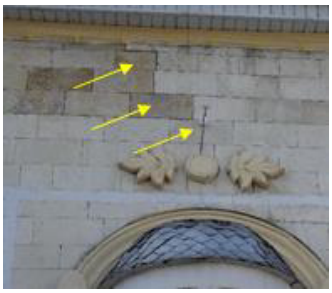

**Fig. 3.** View of inclined cracks in the facade wall.

Other defects were also identified:
- periodic humidification of external and internal walls due to communication leaks;
- there are no lintels over the openings;
- damage to the masonry walls as a result of numerous alterations of the passage of communications;
- damage to the masonry walls in the interface of the main building and the extension as a result of the lack of structural design of deformation seams;
- the movement of the beams covering the extension on the supports, as a result of uneven precipitation of the extension in the axes;
- layering of the masonry of the outer wall of the extension under the supports of the lintels as a result of uneven precipitation of the base of the wall;
- the movement of the coating plates along the outer wall of the extension with the chipping of the masonry.

Cracking of cornices, danger from falling fragments of the plaster layer and the construction of cornices (Fig. 4).

**Fig. 4.** Example of cornice cracking.

During the survey of coating and floor structures, the following main defects were found:
- significant corrosion damage to the steel structures of the technical floor ceiling;
- destruction of the ceiling archs masonry as a result of numerous alterations of structures and the passage of communications;
- weakening of small-sized floor slabs of the technical underground with holes for the passage of communications;
- moistening of the extension cover structures due to roof leaks;
- corrosion damage to the details of the support units and welded seams of the arches of the winter garden cover;
- defects in the manufacture of welded joints of the details of the support units of the arches of the winter garden cover;
- unauthorized removal of supporting structures of technical galleries for maintenance of stage lifts and rigging devices;
- putrefactive damage to wooden flooring structures of technical galleries;
- corrosion damage to the supporting steel structures of the grate. Blind embedment of steel beams in external stone walls. There is no anti-corrosion protection;
- corrosion damage to the overhead corners and the seams of their attachment along the upper belt of the truss trusses to increase the platform for supporting the floor slabs above the auditorium;
- through corrosion damage to steel sheets of the roof of the open gallery (Fig. 5).

**Fig. 5.** View of through corrosion damage of steel roofing sheets.

In the process of the instrumental part of the survey, the hardness of the structural steel of the lantern truss elements was tested, followed by the transition to the scale of the tensile strength of steel, non-destructive testing of concrete structures by the ultrasonic pulse method, and control of the residual dimensions of the walls of the elements with one-sided access, which was performed using the TT100 ultrasonic thickness gauge.

The work on strength measurements by the ultrasonic pulse method was carried out using the Pulsar-1.2 ultrasonic device (Fig. 6), included in the State Register of Measuring Instruments at No. 24690-06.

The device used has oscilloscope modes for viewing and analyzing ultrasonic testing. When determining the speed of passage of an ultrasonic pulse, in concrete and in masonry mortar, visual control of the shape of the pulses of the first entry was performed to exclude the influence of reflected signals and macro cracks.

**Fig. 6.** Determination of brickwork strength by ultrasonic pulse method.

Summing up the analysis, it can be stated that as a result of instrumental and visual inspection of the load-bearing structures of the building at the facility, it was found that the operational reliability and durability of the building structures basically does not meet the requirements of the current regulatory documents. During the inspection of the technical condition, defects acquired at the stage of construction of the building and during operation were revealed.

According to the results of the survey, the general technical condition of the building structures as a whole corresponds to the category of "limited operational", provided that the safety of the building users is ensured in accordance with the requirements of Article 11 No. 384-FZ of 12/30/2009. "Technical Regulations on the Safety of Buildings and Structures".

The control of the reinforcing scheme and the determination of the diameter of the reinforcement were carried out by the magnetometric method using the Poisk 2.5 device (Fig.

7). The device is included in the State Register of Measuring Instruments at No. 26398-09. The principle of its operation is based on registering the change in the electromagnetic field of the sensor during its interaction with the armature. Determination of the thickness of the protective layer and the unknown diameter of the reinforcement is carried out using a standard plexiglass spacer.

**Fig. 7.** View of the control of the reinforcing scheme of reinforced concrete elements by the magnetometric method.

At the same time, to determine the class of reinforcement, control openings of the concrete protective layer were carried out.

In the process of the instrumental part of the survey, the hardness of the structural steel of the elements of the lantern trusses was tested, followed by the transition to the scale of the temporary strength of steel. Steel hardness was measured using a TKM 459C ultrasonic hardness tester (Fig. 8). The TKM 459C device is included in the State Register of Measuring Instruments at No. 45302. The principle of operation of the hardness tester is based on the method of measuring the ultrasonic contact impedance of a diamond tip embedded in a metal surface. The surface of the structures at the control points was pre-treated to a maximum roughness of not more than $R_z$=80. To increase reliability, the value of a single measurement in a series is obtained by automatically performing 11-12 measurements. Each series of measurements is subjected to mathematical processing with the determination of the average value, standard deviation with automatic rejection of incorrect results. Processing of the results is performed automatically according to statistical algorithms, software-built into the device used. The results of hardness determination can be obtained on the HB, HRC, HV or MPa scales (corresponds to the tensile strength of steel).

**Fig. 8.** Hardness testing of steel structural elements by ultrasonic contact impedance using the TKM459S device.

The control of the residual dimensions of the walls of the elements with one-sided access was performed using an ultrasonic thickness gauge TT100 (Fig. 9). The TT100 device is included in the State Register of Measuring Instruments at No. 19411-00. The principle of its operation is based on the ultrasonic contact echo-pulse method of non-destructive testing using longitudinal volumetric ultrasonic waves. The surface of the structures at the points of thickness control was pre-treated to a maximum roughness of not more than $R_z$=80. To create a reliable acoustic contact with the emitter, silicone gel "Contact" was applied to the surface of the construction material.

**Fig. 9.** Determination of the actual wall thickness of sections of steel structural elements by the contact echo pulse method using the TT-100 device.

## 4 Discussions

To increase the reliability of the results of assessing the strength of masonry, laboratory tests of masonry brickwork of the walls of the technical underground as the most loaded structures of the building were carried out. During testing, the strength of bricks in compression and bending was determined in accordance with the requirements of GOST 530-2012, and the brand of bricks for strength was identified.

To control the quality of the material of steel structures, laboratory tests of metal samples taken from structures for quantitative chemical analysis with the determination of the steel grade were performed. The samples were selected from the most loaded structural elements in the form of chips in accordance with the requirements of GOST R ISO 14284-2009.

## 5 Conclusion

After analyzing the results of the survey of the building in question, in order to ensure further safe operation, the need for the following activities was identified:

Ensure the normative technical condition of water-bearing communications to prevent soaking of the subsiding soil of the foundations.

The coating of paving slabs near the walls of the building does not provide protection for the foundation soils and the outer walls of the building from moisture. It is required to make a waterproof coating, to exclude moisture of the walls through the pits, to ensure the slope of the area adjacent to the building to drain surface water from the walls of the building.

To prevent excessive moistening of the internal surfaces of the external enclosing structures with condensation moisture, it is necessary to provide for maintaining the required temperature and humidity conditions in the rooms, basements and technical undergrounds.

Change the system for collecting wastewater from the floor of the open gallery to prevent moisture stagnation and corrosion of the transverse steel beams of the floor, protect the junctions of the steel beams of the gallery floor with columns from atmospheric influences.

Perform corrosion protection of steel structures in accordance with the requirements of SP 28.13330.2012 "Protection of building structures against corrosion";

Perform a set of works to protect the structures of the building and the outer walls of the technical underground from moisture;

Perform a set of works to protect the basement of foundations, composed of subsidence soils, from moisture;

Organize continuous monitoring of the state of the building with the maintenance of a log of observations.

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