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Original Article

Evaluating the Impact of a Comprehensive Technical Building Survey using a Cultural Heritage Site as an Example

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Abstract *- A comprehensive survey of the technical condition of buildings (structures) makes it possible to assess the actual values of the monitored parameters that characterise the serviceability of structures and elements and to predict their reliability and safety in the future. The purpose of the study is to prove that a qualitatively performed comprehensive survey of the technical condition of buildings (structures) is necessary for further reliability and safety of the operation of buildings (structures). The article is based on the assessment of complex inspection of the technical condition of buildings and structures on the example of the object of the cultural heritage of a regional destination - a lodging house located at 3 Malaya Dmitrovka Street, Moscow. It is established that the revealed defects and damages testify to the category of the technical condition of the building as limited operational. The article formulates recommendations for the elimination of the identified defects and damages.*

Keywords *- Due diligence, Technical condition, Construction, Cultural heritage.*

1. Introduction

A comprehensive survey of the technical condition of buildings (structures) makes it possible to assess the actual values of monitored parameters that characterise the serviceability of structures and elements and to predict their reliability and safety in the future.

A poorly executed complex survey of the technical condition of the building and, consequently, not fully presented recommendations for the elimination of defects and damages will not help to avoid negative consequences associated with the comfortable and safe operation of buildings (structures) in the future, which is the problem on which the article is based.

Within the framework of the article, an assessment of the complex survey of the technical condition of the object of the cultural heritage of a regional destination - a tenement house located at 3 Malaya Dmitrovka Street, Moscow.

The purpose of the survey is to determine the significance of correct and complete determination of the technical condition of the building structures and internal engineering networks for their further operation and to formulate recommendations for eliminating identified defects and damages.

The study aims to prove that a high-quality, comprehensive survey of the technical condition of a building (structure) is important and necessary for the future reliability and safety of the operation of buildings and structures.

Fig. 1 Street side facade of the building

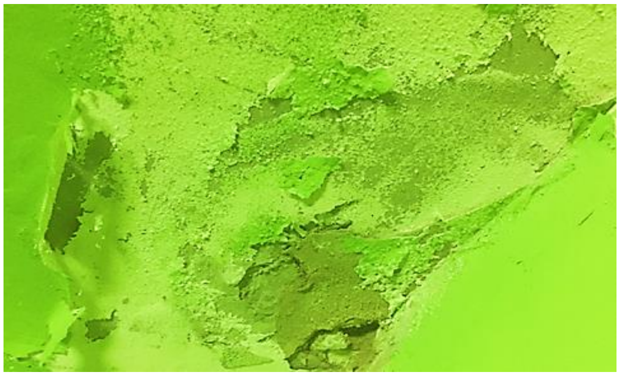

Fig. 2 Sampling location for laboratory testing

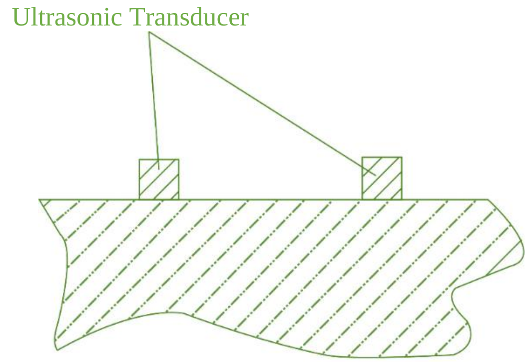

Fig. 4 Schematic diagram of a surface ultrasonic measurement

2. Materials and Methods

A comprehensive inspection of the technical condition of the building includes:

- A preliminary (visual) inspection, the main objective of which is an overall assessment of the technical condition of the building and its structures;
- Detailed (instrumental) inspection including:

1. Measurement of geometric parameters of building structures;
2. Chemical and technological analyses of the building materials;

Research work to be carried out includes field inspection, sampling for laboratory examination, microscopic photographing and sampling locations.

3. Mycological examination of building materials;
4. Survey of foundations and subgrade soils;

To determine the geometric characteristics and materials of foundations, pits are made beneath the external load-bearing walls in A-B/1-2 axes and a brick pillar in A-B/11-12 axes. The foundations of the building are of two types: under the load-bearing walls, there are strip cobble foundations on a complex mortar with the inclusion of brick scrap, and under the columns, there are columnar cobble foundations.

Fig. 3 Pit in axes A-B/1-2

5. Determination of concrete strength of reinforced concrete structures;

Determination of the strength characteristics of concrete load-bearing monolithic reinforced concrete structures is carried out using the methods established by the regulatory documents in force in Russia GOST 18105-2018 and GOST 22690-2015, GOST 17624-2012.

The general test procedure is adopted in accordance with paragraph 4.8 of GOST 18105-2018. The number of tests shall be taken as not less than three for each construction in accordance with the requirements of p. 4.3 of GOST 18105-2018 and p. Zh2 of the annexe Zh of GOST 22690-2015.

To determine the strength class, the tests are performed by the shear-off and ultrasonic methods, specifying the appropriate graduation curves.

According to the program of works, 15 tests will be carried out by the chipping-breaking method, 60 tests by the ultrasonic method and 60 tests by the shock-pulse method.

The shear-bar method is based on the existence of a design relationship between the resistance of concrete to uniaxial compression R and the anchor pull-out force P. The method makes it possible to determine the compressive strength R in the structure without or with a small volume's local fracture.

At the moment of concrete spalling, the instrument records the pull-out force P and converts it into the concrete strength R, calculated according to the formula:

$$R = m_1 m_2 m_3 P, \quad (1)$$

where P is the tearing force of the anchoring device;

m_1 - coefficient taking into account the maximum size of coarse aggregate in the tearing-out zone;

m_2 - the proportional coefficient for the transition from tearing force to the compressive strength of concrete;

m_3 - factor that takes into account the value of the actual depth of disruption.

The ultrasonic method of concrete strength control is one of the methods of nondestructive testing of building structures. This method is based on a correlation between the velocity of longitudinal waves in a structure and the strength of concrete.

Processing of test results is conducted in accordance with Section 7 of GOST 18105-2018. The actual concrete strength class was determined using the formula:

$$B_{fact} = R_m / K_t, \quad (2)$$

where R_m is the average strength of the concrete according to test results;

K_t - coefficient of required strength.

V - coefficient of variation of concrete strength defined by the formula:

$$V = S_m / R_m, \quad (3)$$

where S_m is the standard deviation of the strength.

When processing the shear-bar test results, the standard deviation is determined by the formula:

$$Sm = \sqrt{\sum (R_i - R_m)^2 / (n-1)}, \quad (4)$$

where R_i is the concrete strength of a single section of the structure tested by the shear-bar method;

n - number of sections.

V_{fact} is the strength of the concrete obtained from the tests carried out and the processing of the data obtained.

6. Determination of the strength of bricks and mortar of load-bearing structures;

The instrumental tests are carried out by the impact-pulse method. In the field, it is carried out with the building material strength meter “ONIKS-2.5”.

The strength of bricks and masonry mortar is determined by means of the corresponding bending curves depending on the rebound value of the striker. The tare curves used to determine the brick strength are based on the results of a sufficiently large number of previously carried out brick tests by means of destructive and nondestructive methods.

The results are statistically processed. The strength estimation is carried out according to the average value of R_{av} from n measurements carried out in each location. The coefficient of variation is calculated:

$$\nu = \sigma \sqrt{R}, \quad (5)$$

where $\sigma = \sum (R_i - R_m)^2 / (n-1)$ – standard deviation.

The conditional compressive strength of the material is determined using the formula:

$$B = R_{av} \cdot (1 - t\alpha\nu), \quad (6)$$

where tα – Student coefficient.

The tests are carried out at 35 conditional points. At each point, 10 rebound measurements are taken from the sclerometer's striker.

7. Determination of reinforcement parameters and floor composition;

The results of the stripping and probing will determine the reinforcement parameters of the reinforced concrete structures, the thickness of the protective layer, and the composition of the floors.

8. Determination of the moisture content of materials;

The moisture of materials is determined by electronic moisture meter Condtrol Hydro-Test according to GOST 29027-91 "Moisture meters of solid and bulk materials. General technical requirements and test methods".

- Survey of engineering networks, including automatic fire alarms, fire alarm notification and evacuation control systems, CCTV systems, structured cabling, intercom system, access control system, CCTV system, electrical equipment and lighting, lifts, ventilation and air conditioning, heating system, and water supply and sewerage;
- Verification calculations of load-bearing structures.

3. Results and Discussion

3.1. Results

Based on the results of a comprehensive engineering survey of the building located at 3 Malaya Dmitrovka Street, Moscow, the following was established:

According to the results of visual inspection of building structures, the most common defects are cracks up to 3 mm in reinforced concrete structures, peeling of the concrete surface, insufficient protective layer and surface corrosion of reinforcement of reinforced concrete structures, foreign inclusions in concrete body, on all floors segments of dismantled steel studs pass through monolithic reinforced concrete beams and floor slabs, and reinforcement of structures in these places is broken, chipped and poorly vibrated areas, multiple cracks.

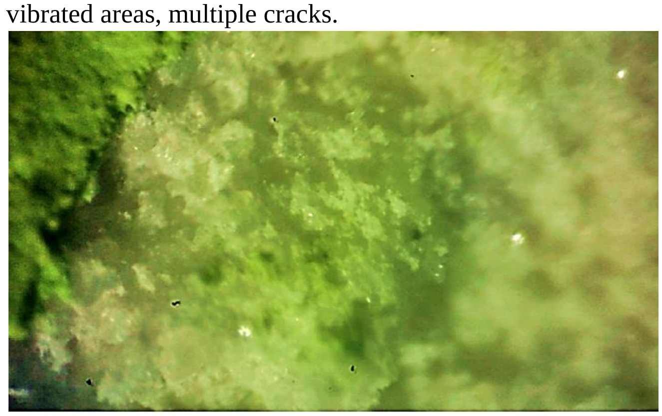

Fig. 5 Microscope surface of a selected sample

As a result of the measurement work, floor plans of the above-ground and below-ground floors, sections with building elevations and a plan of the rafter system have been generated.

The results of chemical and mycological investigations revealed the following:

- Analysis of the results of salt composition in building materials indicates that the wall finishing materials are subject to type II corrosion and type III corrosion, according to the accepted classification;
- B Microbiological examination revealed microscopic fungi infesting the surveyed samples. Under favourable conditions, they can rapidly spread over the surface of the materials and cause damage not only to the surface appearance but also to the structural failure of the material.

Based on the results of tests of the monolithic load-bearing reinforced concrete structures, the actual strength of the concrete has been established.

Brick and masonry mortar of the load-bearing structures were tested, and their types and grades were determined.

Based on the stripping and probing results, the reinforcement parameters of reinforced concrete structures, the thickness of the protective layer, and the composition of floors have been determined.

According to the results of the determination of moisture content of building materials, it was established:

- The average moisture content of the timber elements of the rafter system is 1.5-5.1%, which does not exceed the permissible value of 20%, according to SP 28.13330.2017 “Protection of building structures against corrosion”.
- CThe average moisture content of the brick basement walls is 7.5%, which exceeds the allowable value of 2%, according to SP 28.13330.2017, “Protection of building structures against corrosion”.
- The average moisture content of the plaster layer is 4.9%, which exceeds the permissible value of 0.6%, according to SP 28.13330.2017, “Protection of building structures against corrosion”.

The results of the inspection of the engineering systems are as follows:

- The technical condition of the automatic fire alarm network is assessed as unserviceable;
- No warning and evacuation control system in place, not implemented;
- Technical condition of the CCTV system is assessed as non-operational;
- Technical condition of the structured cable network is assessed as non-operational;
- The technical condition of the intercom system is assessed as unserviceable;
- The technical condition of the access control and management system is assessed as unserviceable;
- Technical condition of the TV system is assessed as inoperable; the technical condition of the EOM section is assessed as inoperable;
- The technical condition of the electrical and lighting section is assessed as limited operational;
- Technical condition of the three lifts is assessed as limited operational; the condition of electromechanical lift equipment, winch and pit structure is satisfactory;
- The technical condition of the ventilation and air conditioning systems is assessed as limited operational;
- The technical condition of the heating section is rated as limited operational;
- Technical condition of water supply and sewerage is rated as limited operational.

The load-bearing capacity of the columns, floor girders, floor slabs and the steel girder of the basement floor has been determined as a result of the verification calculations. The load-bearing capacity is ensured.

The category of the technical condition of the building located at 3 Malaya Dmitrovka Street, Moscow, based on the survey in accordance with GOST 31937-2011 "Buildings and Structures. Rules for Inspection and Monitoring of Technical Condition" is assessed as limited operational.

The reasons for the identified defects and damages are poor quality restoration works, lack of long-term conservation of the building under construction, flooding of the basement floor due to the unsatisfactory state of the building's foundation waterproofing, groundwater drainage system and drainage from the roof, violation of temperature and humidity conditions due to lack of proper ventilation.

3.1.1. Recommendations for Remedying Defects and Damage

The following work is recommended to remedy the defects and damages revealed by the survey:

- Eliminate causes of leaks and wetting in basements and ground floor rooms by repairing or replacing drainage and drainage systems and restoring waterproofing of foundations;
- Repair and restore the finishing layer of the building's facades and the interior finishing layer of walls, ceilings, and floors of staircases;
- Perform perimeter paving of the building;
- Completely remove contaminated building materials, clean structures and treat with special antiseptic and biocidal agents, dry and remediate;
- Corrosion removal, anti-corrosion treatment and restoration of the protective layer on steel components;

- Replace damaged door units and insulated window units;
- Installation of window frame gaskets to prevent precipitation from entering the building through gaps and restoration of eaves;
- Perform overhaul of roofing to prevent precipitation from entering the building and facades;
- Replace eaves and gutter heating;
- Perform repair of drainage system;
- Develop a working project for engineering networks in accordance with current norms and taking into account installed equipment.
- To carry out the replacement of engineering systems according to specially designed projects;
- Perform restoration of the protective layer of reinforced concrete structures with a preliminary scraping of bare reinforcement cage from corrosion products and anticorrosive treatment;
- Perform repair and restoration work on concrete structures in the area of spalls, scallops and caverns with repair compositions;
- Due to the absence of construction and installation works at the site and its operation for a long time, it is recommended to carry out works to clarify the engineering surveys;
- Based on the results of the engineering and geological surveys and taking into account the developed design solutions to strengthen the structures, perform verification calculations of the entire building;
- Carry out reinforcement of the supporting structures according to a special design and recalculate the estimate taking into account the reinforcement;
- Carry out and implement the design of a geodetic monitoring system for operational, technical solutions and preservation and loss prevention measures for the cultural heritage object;
- Carry out adjustments to the design documentation to take account of identified defects and damage to the actually installed structures. The design documentation shall be developed in accordance with the current normative and technical documentation. Identify by design the structures to be retained and how they will be reinforced and rehabilitated.

All structural reinforcement and defect repair work must be carried out according to a specific design by a specialised organisation authorised to carry out this type of work.

3.2. Discussion

The following categories of the technical condition of the building's structures have been established in accordance with GOST 31937-2011 based on the results of the comprehensive survey:

- The technical condition category of the foundations is assessed as limited workable;
- The technical condition category of the walls is assessed as limited operable, with the exception of the basement foundation wall in A-B/3 and the ground floor partitions in B-D/4, which are assessed as failing;
- Category of the technical condition of the slab and floor structures are assessed as limited operable, with the exception of the first floor floors, which are assessed as operable;
- The technical condition category of the roof structures is assessed as limited operable.

Thanks to a high-quality, comprehensive survey of the technical condition of the building (structure), a not insignificant number of damages and their causes were identified. This has helped to make recommendations for the full elimination of defects and will allow for their elimination together with the causes of their occurrence.

Had the survey been carried out less well or to a lesser extent, not only would it not have been possible to remove the existing defects and damage? However, it would also have been possible to identify the causes of the damage, and, as a result, the building (structure) would have lost its capacity to function to an even greater extent.

4. Conclusion

Assessment of the complex survey of the technical condition of the building (structure) was carried out using the example of a regional cultural heritage object - a revenue house located at 3 Malaya Dmitrovka Street, Moscow. It was established that the category of technical condition of the building is assessed as limited working. However, defects and damages were revealed during the examination, and recommendations for their elimination were given. Thus, the proposed hypothesis is proved to be true, that qualitative complex inspection of the technical condition of the building (construction) is important and necessary for further reliability and safety of the buildings and structures operation.

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