*Original Article*

# Influence of the Results of Verification Calculations of the Building on the Comprehensive Examination and Determination of the Technical Condition of the Bearing Structures of the Building

Yana Shesterikova[1], Maria Koroteeva[1*], Tembot Bidov[1], Rustam Fatullaev[1]

[1]Department Technologies and Organization of Construction Production, National Research Moscow State University of Civil Engineering (NRU MGSU), Moscow, Russia.

[*]Corresponding Author : maria.krtv@vzdv.ru

*Abstract - Comprehensive inspection of buildings (structures) contributes to obtaining data on the object's current state, identifying the category of technical condition, confirmation or refutation of further performance of building structures, engineering and other characteristics. Thanks to such a system of observation and control, it is possible to establish the state of the building and its load-bearing elements in advance. However, the main factors influencing the result of the study are the verification calculations, which are carried out after a thorough visual inspection to determine the bearing capacity of the building or part of it. The purpose of the study is to determine the significance of verification calculations to establish the category of the technical condition of the building (and)or structure. The article is devoted to the influence of the results of the building's verification calculations on the complex examination and determination of the technical condition of the load-bearing structures of the Dolgorukov-Bobrinsky urban manor, 2nd half of the 18th century - 19th century. The main house, 2nd half of the 18th c. - 19th c. XVIII c., 1793, 1819, 1853-1856, located at the address: Moscow, Malaya Dmitrovka Street, 1, building 1. The study of the object is necessary to draw up measures for the preservation and prevention of loss of the object of the cultural heritage of regional importance, for its restoration and strengthening for further commissioning. The article proves the validity of the hypothesis put forward about the weight of the influence of verification calculations on the accuracy of determining the category of the technical condition of the building or its part.*

*Keywords - Comprehensive survey, Verification calculations, Technical condition, Visual and instrumental control, Measurement work, Cultural heritage object.*

## 1. Introduction

A comprehensive inspection of buildings (structures) contributes to obtaining data on the object's current state, identifying the category of technical condition, confirmation or denial of further performance of building structures, engineering and other characteristics. [1,2,3]

Thanks to the observation and control system, it is possible to establish the condition of the building and its load-bearing elements in advance.

The article is devoted to the influence of the results of verification calculations of the building on a comprehensive examination and determination of the technical condition of the supporting structures of the Dolgorukov-Bobrinsky urban manor, 2nd half of the 18th century - 19th century. The main house, 2nd half of the 18th c. - 19th c. XVIII c., 1793, 1819, 1853-1856, located at the address: Moscow, Malaya Dmitrovka Street, 1, building 1.

According to the conclusion of the visual inspection of the building structures of the Dolgorukov-Bobrinsky urban manor was determined:

- The technical condition of the building foundations is assessed as limited working. There are areas of masonry delamination and falling out of individual stones, no vertical and horizontal waterproofing, and pits are flooded.
- The technical condition of the external and internal walls of the building is assessed as limited-working, except for the basement foundation wall in the A-B/3 axes, which is assessed as an emergency. Identified cracks with more than 3 mm opening, weathering and destruction of brickwork, bioporation, and bulging of the outer wall of the basement in axes A-B/3.

- The technical condition of the floors and ceilings of the building is assessed as serviceable, except for the floors of the first floor, which are assessed as limited serviceable. Numerous areas of swelling and destruction of the flooring of the first floor, areas of destruction of the floor screed, traces of leaks and wetting, and bio-damage are revealed.
- The technical condition of the building's roof is assessed as limited working. Multiple holes in the roofing sheet, corrosion and deformations of roofing elements, multiple breaks of heating cable, cracking of sealant, and deformations of drainage gutters are detected.

Thus, a comprehensive engineering survey and assessment of the technical condition of the building structures to determine the causes of the partial collapse of the building structures.

## 2. Materials and Methods

A comprehensive engineering survey of the building is performed in accordance with the requirements of the approved technical assignment and work program and regulatory and technical documentation. [12-22]

Visual and instrumental control (VIC) was part of the complex of works to assess the technical condition of the object. The main task of the visual inspection is an overall assessment of the technical condition of the building and its structures. Based on the visual inspection results, the need for further instrumental examination is determined.

At the stage of visual inspection, the structural scheme of the building was determined, the load-bearing structures on the floors and their location were identified, and the space-planning solutions in combination with the structural scheme of the building were analyzed. Visual inspection also revealed the condition of the supporting structures, the presence and width of the crack opening of concrete, reinforced concrete structures, the value of poorly compacted areas of concrete, the presence of efflorescence, assessment of the degree of corrosion damage to steel structures, the state of corrosion protection coating, the presence of structural damage, cracks.

Measurement work was carried out with a laser rangefinder, a standard tape measure and a caliper. Structural deviations were controlled with a plumb line and level. Geodetic measurement of structures was performed by high-precision electronic total stations and levels designed to obtain data on the planned position, height coordinates and exact dimensions of the building elements. Computer processing of data was performed using specialized software (Autocad, Geoterminal, etc.).

Pits were made under the external load-bearing walls in the axes B-B/1-2 and A-B/3-4 to determine the geometric characteristics and materials of the foundations. The foundations of the building under the load-bearing walls are taped rubble on a complex mortar with the inclusion of brick rubble.

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

The general test procedure was adopted in accordance with paragraph 4.8 of GOST 18105-2018. The number of tests was taken equal to at least three for each design, in accordance with the requirements of paragraph 4.3 of GOST 18105-2018 and paragraph Zh2 of Annex Zh of GOST 22690-2015.

To determine the strength class, tests were carried out by shear breaking and ultrasonic method, with the specification of the appropriate graduation dependencies.

When examining the strength characteristics of monolithic load-bearing reinforced concrete structures, the shear-breaking method used an electronic strength meter of building materials, the device "Onyx-OS". The rebound shear method is based on the existence of a design correlation between the resistance of concrete to uniaxial compression R and force P of anchor tearing out of concrete. The method allows determining the strength of concrete in compression in the structure R without destruction or with local destruction of a small volume.

The tests were done in the following sequence (Fig. 1):
- In the surveyed areas, boreholes ∅ 24 mm and 35 mm deep were made. The boreholes were made with an impact-rotating tool perpendicular to the surface.
- In the boreholes drilled with a special boring device, an annular groove was made to ensure reliable concrete bonding with the anchor.
- The anchor assembly with segments was installed into the borehole in such a way that the protrusions of the segments fell into the slot.
- Screwed on the threaded shank of the anchor rod D and tightened with a wrench S = 19 mm, the press was installed on the rod through the center hole of the housing and screwed on the threaded end of the rod hand wheel E.
- Turning the press around, the rod found a stable position for the support and convenient for the handle F of the drive.
- The handwheel E was tightened, creating a pre-tensioning of the tie rod with the anchor necessary to

securely base the press on the surface of the concrete at three anchor points.

- The press was uniformly loaded at the same speed, rotating the handle F until the concrete was chipped. At the moment of concrete chipping, the device recorded the breaking force P and converted it to concrete strength R, MPa, calculated by the formula:

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

where $P$ is the tensile force of the anchoring device, kN;

$m_1$ - coefficient, taking into account the maximum size of the coarse aggregate in the breakout zone;

$m_2$ - proportionality factor for the transition from the breakout force, kN, to the compressive strength of concrete in MPa;

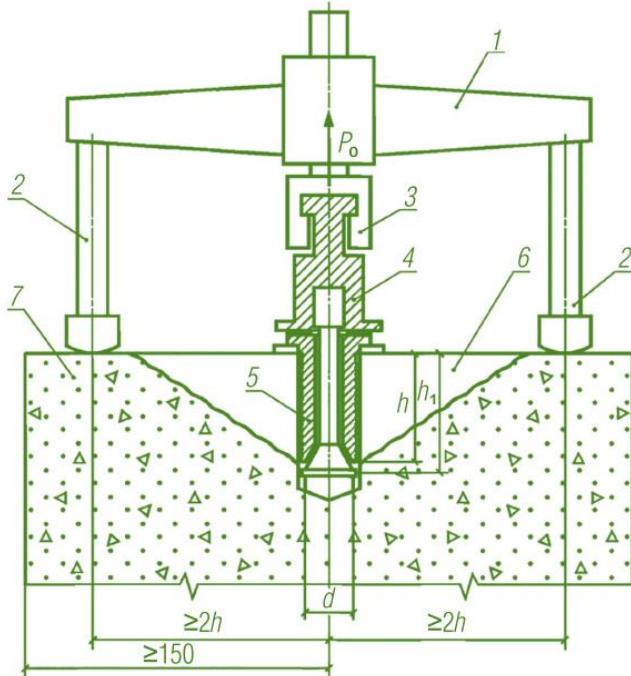$m_3$ - coefficient, which takes into account the value of the actual depth of excavation.



**Fig. 1 Test scheme**

In determining the strength characteristics of monolithic load-bearing reinforced concrete structures used, ultrasonic flaw detector Pulsar -1.1.

In the process of measurements, the ultrasonic wave velocity was determined in the volume of the structure between the source and the receiver. Surface sounding was used.

Surface sounding measures the transit time of the longitudinal wave. Surface sounding is sensitive to heterogeneities and defects in the near-surface layer (cracks, presence of plaster and its peeling). PULSAR 1.2 devices produced by SPE "Interpribor" was used in the works on the object.

There is a need to clarify the graduation dependence of the shear-off and ultrasonic methods.

In the structures, the value of concrete strength was determined by an indirect non-destructive ultrasound method. In the same points of the structures, the parallel determination of the concrete strength by the direct non-destructive method - the method of tearing off with shear, according to GOST 22690-2015 was carried out. The number of parallel determinations of the concrete strength for each group of one-type structures, according to the appendix Ж of GOST 22690-2015, is not less than three. There was performed calibration of the readings obtained by the ultrasound method according to appendix "G" to GOST 17624-2012 according to the formula of the universal calibration relation: R = (0,016V - 27,3) and as a result, the calibration relationship between the two methods for each group of the same-type structures was specified. To clarify the results obtained using the universal calibration dependence, the readings were multiplied by the coefficient of coincidence Kc, determined by the formula:

$$K_c = \frac{\sum_{i=1}^{n} \frac{R_{o.c.i}}{R_{узк.i}}}{n}, \qquad (2)$$

where

$R_{o.c.i}$ – concrete strength in the section, determined by the method of tearing away with shear;

$R_{узк.i}$ – the strength of concrete in the section, determined by ultrasonic method;

$n$ - the number of sites, taken at least three.

When calculating the matching coefficient, the following conditions were met:- each incremental value $\frac{R_{o.c.i}}{R_{узк.i}}$ must be at least 0.7 and no more than 1.3.

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

$$B_{факт} = \frac{R_m}{K_t}, \qquad (3)$$

where

$R_m$ - – average strength of concrete according to test results;

$K_t$ - factor of required strength.

$V$ - coefficient of variation of concrete strength, determined by the formula:

$$V = \frac{S_m}{R_m}, \qquad (4)$$

where

$S_m$ – strength mean square deviation.

During the processing of the test results by the shear-bar method, the root mean square deviation was determined by the formula:

$$S_m = \sqrt{\frac{\sum(R_i - R_m)^2}{n-1}}, \qquad (5)$$

where

$R_i$ – concrete strength of a separate section of the structure tested by the shear-bar method;

$n$ - lot size.

$B_{факт}$– the strength of the concrete obtained from the results of the tests and processing of the data obtained.

The instrumental tests by the shock-pulse method in the field were carried out with the measuring device of building materials strength "ONIKS-2.5. Universal measuring of the strength of building materials "ONIKS-2.5" is designed for rapid determination of the compressive strength of building materials by a non-destructive, shock pulse method (GOST 22690-2015, GOST 18105-2018 and SP 15.13330.2020) for technological quality control, an inspection of buildings and structures. It determines the hardness, uniformity, density and plasticity of various materials. The device "ONIKS-2.5" consists of a sensor-sclerometer, peak detector, signal microcontroller (SMC), matrix liquid crystal display (MLCD) and a keyboard.

The strength of bricks and masonry mortar was determined by the corresponding calibration curves depending on the rebound value of the striker. The tare curves used to determine the strength of bricks are based on comparing the results of a sufficiently large number of previously conducted tests of bricks by destructive and non-destructive methods. The brick strength results given in this technical report are estimates.

Statistical processing of the material test results was also performed. The strength was evaluated by the average R-value from n measurements performed in each location.

$$R = \frac{\sum R_i}{nR}, \qquad (6)$$

where

$R_i$ - strength by separate measurement.

The coefficient of variation was calculated by the formula:

$$\nu = \frac{\sigma}{R}, \qquad (7)$$

where $\sigma = \frac{\sqrt{\sum(R - Ri)^2}}{n-1}$ – standard deviation.

Determination of the conditional compressive strength of the material was carried out according to the formula $B = R \cdot (1 - t_\alpha \nu)$, where $t_\alpha$ is the student coefficient. Tests were carried out in 15 conditional points. At each point, 10 measurements of the rebound of the sclerometer's striker were made.

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

Thus, with the help of the software package SCad office, the collection of loads on the partition of the building in the basement was performed (Fig. 2). After that, verification calculations were made (Fig.3) in order to calculate the load-carrying capacity of the loaded walls of the research object. The obtained utilization factors should be analyzed, and further behavior of the element should be determined since the result can influence the course of a comprehensive technical inspection of the building (and) or structure.

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**Load on piers**

**II - (1700x700):**

**- ceiling (above the pier):**

**13, 75x(442, 3 + 50) = 6769 kgf**

**- attic floor:**

**13, 75 * 391 ,9=5388 kdf**

**- useful (above the pier):**

**13, 75 * 245 = 3369kgf**

**- useful from attic floor:**

**13, 75 * 93 = 1279kgf**

**- roof and snow:**

**13, 75 x 394 = 5417kgf**

**weight of masonry:**

**5 ,6 x 0,77 x 2,92 x 1800 x 1,1=24930 kgf**

**Longitudinal force 47,15 tf**

**Eccentricity from application of load from the above ceiling:**

**For load 10,14 tf 0,1 m**

**Total eccentricity (for force 47,15 tf): 0,02 m**

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**Fig. 2 Calculation of the partition Pr-1**

## 3. Results

According to the results of a comprehensive engineering survey of the building:

Dolgorukov-Bobrinsky Urban Estate,
2nd half of the 18th century - 19th century - Main House,
2nd half of the 19th century. XVIII c. - XIX c. - Main House,
2nd half. XVIII century, 1793, 1819, 1853-1856, located at Moscow, Malaya Dmitrovka Street, 1, building 1., it has been established that:

**Simply**

L = 6,8 m
Q = 1,5 T/m

B = 770 mm
Az = 150 mm
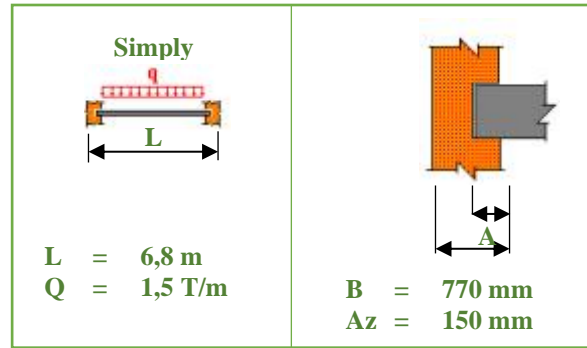
| Calculation | | |
|---|---|---|
| **Tested by SNiP** | **Test** | **Utilization** |
| Para. 7.13 SP 15.13330, para 7.3 Designer's guide | by crushing brickwork under the beam support | 3,01 |

**Utilization rate 3,011 - By crushing brickwork under the beam**

**Fig. 3 Determination of the coefficient of utilization on the buckling of masonry partition Pr-1**

- The most common defects of building structures are the destruction of the finishing layer, efflorescence, traces of leaks and soaks, areas of water stagnation in basements, cracks up to 3 mm in the finishing layers, hair cracks in the finishing layer, bio damage to the basement, weathering and destruction of masonry facades, corrosion of steel elements of facades, destruction of the finishing floor layer, bloated floor screed, in the places of the opening of the floors found embedded in the screed wires electricity in close proximity to the heating pipes, peeling roofing sheets, violation of the integrity of the roof mat, folds are broken in some places, there is mechanical damage to the metal in the form of through holes, corrosion of local areas of the roof and metal fence, breaking the line of heating eaves and trays, deformation of gutters. The basement wall in axes 3/A-B is in an emergency condition. There are cracks with more than 3 mm opening and bulging of the wall, according to the results of measurement works, floor plans of the above-ground and underground floors, sections with the height marks of the building, and the scheme of the rafter system.

According to the results of the examination of foundations and subsoil found:
- Building foundations, ribbon, the upper part is made of clay bricks, and the lower part is made of masonry.
- No vertical and horizontal waterproofing of foundations.
- The depth of laying strip foundations of the building walls from the basement floor level is 650-750 mm. Type of soil in pits № 1 - gravelly sand, in pits № 2 - fine sand.

According to the results of tests of monolithic load-bearing reinforced concrete structures, the actual strength of concrete was established.

- For monolithic reinforced concrete floor slabs and floors: $B_{факт}$ 27,0 MPa, which corresponds to class B25;
- For monolithic reinforced concrete pylons: $B_{факт.}$ 25,01 MPa, which corresponds to class B25.

According to the results of tests of bricks and masonry mortar of supporting structures established:
solid brick walls of the first floor in axes D/3-4, D1-D/4, G/5, A/4-5 - M25;
solid brick walls of the first floor in axes A/1-2, B/1-2, Zh/1-I/5/1-5/2, V-G/5-6 - M50;
solid brick walls of the first floor in axes A/3-4, V-G/5-6 - M75;
solid brick walls of the second floor in axes E-Zh / 5/1, D/1-E / 6/1, D/1-D / 5-6, Zh1-I / 5/1, V / 3-4, B / 3-4 - M150;
masonry mortar in axes A/3-4, B-G/5-6, A / 1-2, Zh/1-I/5/1 - 5/2 - M25;
Masonry mortar in the axes V-G/5-6, E-Zh / 5/1, D/1-E / 6/1, D/1-D / 5-6, Zh1-I / 5/1, V / 3-4, B / 3-4 - M50.

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

The results of determining the moisture content of building materials established:
- The average moisture content of wooden elements of the rafter system is 1 - 4.1%, which does not exceed the allowable value of 20%, according to SP 28.13330.2017 "Protection of building structures from corrosion.
- The average moisture content of brick walls of the basement is 8%, which exceeds the allowable value of 2%, according to SP 28.13330.2017, "Protect building structures from corrosion.

- The average moisture content of the plaster layer is 4.9%, which exceeds the allowable value of 0.6%, according to SP 28.13330.2017, "Protection of building structures from corrosion.

According to the results of the verification calculations, it was established:
- The bearing capacity of the brick wall of the basement in axes A-B/3 is not provided; the utilization factor is more than 1.5;
- The bearing capacity of the walls under the action of longitudinal forces is ensured; the coefficient of bearing capacity use is 0.71;
- The bearing capacity of the walls in the buckling under the supports of the beams is not provided; the coefficient of bearing capacity is 3.011 - walls on the axis of the V-D/4.

According to the results of a comprehensive inspection, the following categories of technical condition of building structures in accordance with GOST 31937-2011 are established:
- The category of the technical condition of the foundation structures is assessed as limited-working;
- The technical condition of the walls is assessed as limited operable, with the exception of the basement foundation wall in A-B/3 axes and the first floor partitions in V-D/4 axes, which are assessed as an emergency;
- The technical condition category of the floor and ceiling structures is assessed as limited operable, except for the floors of the second floor, which are assessed as operable;
- The category of technical condition of the roof structures is assessed as limited working.

Technical condition category of the building "Dolgorukov-Bobrinsky Town Estate, 2nd half of the 18th century - 19th century. The main house, 2nd half of the XVIII c. - XIX c. XVIII c., 1793, 1819, 1853-1856, located at the address: Moscow, st. Malaya Dmitrovka, 1, building 1, based on the survey, according to GOST 31937-2011 "Buildings and Structures. Rules for Inspection and Monitoring of Technical Condition" is assessed as limited-operable, except for the basement wall in A-B/3 axes, which is assessed as an emergency.

The reasons for the identified defects and damages are poor-quality restoration work, lack of conservation of the building under construction, the unsatisfactory condition of the waterproofing of the building foundations and groundwater drainage system (drainage), and violation of temperature and humidity conditions due to lack of proper ventilation.

## 4. Discussion

Based on the survey of the buildings of the Dolgorukov-Bobrinsky Town Estate, the 2nd half of the 18th century to the 19th century, the Main House, 2nd half of the 19th century. The main house, 2nd half of the 18th century, 1793, 1819, 1853-1856. XVIII c., 1793, 1819, 1853-1856, located at the address: Moscow, st. Malaya Dmitrovka, 1, building 1, the technical condition of the object was defined as limited working except for the basement wall in A-B/3 axes, which is assessed as dangerous. Thus, to eliminate defects and damages revealed as a result of the survey, it is recommended to carry out works on strengthening and restoration of structures, as well as the elimination of causes of deformations leading to the destruction of the building. It was possible to correctly determine the technical condition of the object under survey only thanks to verification calculations performed on the basis of data obtained as a result of a detailed instrumental survey.

## 5. Conclusion

Without a thorough examination of the buildings of the Dolgorukov-Bobrinsky Town Estate, the 2nd half of the 18th century to the 19th century, the Main House the 2nd half of the 19th century. The main house, 2nd half of the 18th century, 1793, 1819, 1853-1856. XVIII c., 1793, 1819, 1853-1856, located at the address: Moscow, st. The object would have been considered exploitable in Malaya Dmitrovka, 1, building 1, based only on visual defects and damage. However, verification calculations to determine the building structures' bearing capacity revealed an emergency element of the building, which fundamentally changes the category of the technical condition of the building. The identified result is necessary to draw up measures to preserve and prevent the loss of the Object of cultural heritage.

## Acknowledgments

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