Complex research of the operational integrity of the solid reinforced concrete floor on the results of the field observations and information modeling data

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Abstract. The article presents the results of a complex of exploratory work and field observations, which made it possible to obtain comprehensive data on the operational integrity of building structures of solid reinforced concrete floors of a commercial building reinforced with composite materials, and to compare them with information modeling data and design solutions.

Introduction
The construction of facilities intended for the stay of a large number of people is associated with certain risks, which are transferred to the responsibility for the design and execution of the supporting building structures of buildings being erected. In modern design conditions, specialists use advanced information technologies in the form of the design software systems allowing designers to obtain not only qualitative but also quantitative indicators for the design of building structures. However, with all the variety and quantity of software products, the main and decisive word stands directly behind the designer, so the result of the calculation depends on the design scheme that the designer takes. In this case, the options of design schemes in a particular solution may not be just one, but the designer who makes the choice is always sure of the correctness of his decision and defends his position, moreover, the current technical standards allow variant decision making. In order to assess the accuracy of technical decisions in the design of building structures, there is always a way to evaluate their bearing capacity - field tests.

Roof structure analysis
Full-scale tests require certain financial costs, therefore, in construction, it is used quite rarely, dispensing with the guarantee of a positive conclusion from the expertise of project documentation, and they apply, mainly in scientific works, experimental studies based on the principles of modeling and certain techniques for conducting them [1]. However, in case the building structures are made without deviations from the design decisions, the defects that are classified as deviations from the normative state appear, then the customer resorts to the full-scale tests to determine the actual technical condition of the building structures. So far, the only document that regulates the methods and rules for testing building structures is GOST 8829-94 [2]. This document may not always determine the scope of planned activities, but may outline some of the stages that should be in the tests conducted. Therefore, comprehensive studies in combination with full-scale tests of building structures are not only relevant, but also have elements of scientific research, information about which can be used in assessing the stress-strain state of the elements of the building frame during its operation under various loading conditions.

Goal statement
The need for a field test was caused by:
- the cracks presence (shrinkage) in the lower part of the floor slab of the basement and the second floor with an opening width of up to 2 mm;
- the difference between the reinforcement calculated values of the solid reinforced concrete grillage from the design decisions (exceeds 5-6 times);
- the difference between the calculated reinforcement of the part of the columns from the design solutions (2.5 times greater - these columns were reinforced with a frame from a steel corner at the time of the test);
- under-reinforcement by 26% of the basement slab lower zone in the E1-Ix13-15 axes (the slab is reinforced with scrim); under-reinforcement of the transit zones along the lower edge of the 1st floor slab in the alignment between the columns in the E1-1313 axes and spans in the axes D-Ex13-15 and E/I-Ix13-15 (slab reinforced with carbon fiber canvases);
- the calculated deflections of the floor slabs and coverings are close to the maximum allowable.

For testing, a work program has been developed in accordance with the requirements of [2]. The program of field tests of building structures of ABK, included the following sections:

1. The operational reliability definition of the object according to [2] and the possibility of its further safe operation under the regulatory load;
2. The bearing capacity determination by an indirect method (taken due to the fact that the structure will not be brought to failure, and the maximum value of the applied static test load when tested, is assumed to be 30% of the normative);
3. The structure rigidity establishment, detected by the values of displacements, limiting from the point of view of the object of normal operation;
4. The crack resistance establishment (when determining crack resistance, set the values of the load at which cracks are formed that are acceptable under the conditions of operation);
5. Determination of the deformation actual values of the foundation structures under regulatory loads;
6. The issuance of a conclusion on the technical condition of the building and the possibility of its further safe operation.

All the works envisaged by the works program were divided into three stages - preparatory work, field tests with static load and plotting the survey.

Preparatory work (stage 1) included:
- analysis of the existing design and technical documentation for the building;
- verification of mounted load devices and prepared load;
- coordination of technical interruptions in the facility operation at the research time;
- drawing up a working scheme of the tested structures (establishing specific zones where the measurements will be made (refer with fig. 1));
- determination of the required accuracy and measurement range, selection of instrumentation with the necessary parameters;
- fixing and drawing up the layout of sediment marks recorded in the test area (columns and ceilings);
- fixing and charting the location of temporary and permanent beacons to determine the crack opening dynamics;
- fixing and charting the location of the reflective marks to determine the dynamics changes in the columns' inclinations;
- perform the 1st cycle of geodesic observations (marks of sedimentary marks, sizes of beacons and rolls of columns) with a load of structures of 0%;
- clarification of the test load, the displacements values, deformations, stresses and forces arising in the studied structural elements.

Field tests by static load (stage 2):
- carrying out the loading of structures with a load constituting 30% of the normative, for comparing the actual controlled parameters (deflections, rolls, draft and displacements) with the calculated values (obtained in the Lyra CAD software complex);
- loading in 4 stages in accordance with the working scheme, alternately loading 25% of the control load (take the load as 30% of the standard load, see figure 1), after which the design in one stage is unloaded to zero and reports are removed. Instrument reports should be removed 20 minutes after each load stage, and also the state of the structures should be inspected. When the test load is reached, ensure its exposure for 30 minutes. The loads measurement is performed by weighing loads. Loading areas must be loaded evenly, without shocks and jolts;
- in the research process, a log and test sheet are kept, where the instruments reports, the cracks measurement data and the structures behavior are entered.
Plotting the survey (stage 3) - according to the survey results of structures after the tests, an analysis of the test results is carried out and a conclusion is drawn up about the technical condition of the building structures of the ACS of a commercial building and the possibility of its further safe operation.

**Figure 1.** Working scheme of the tested structures at mark +5,170 indicating the maximum values of the applied load

**Results**
The overlapping fragments were loaded with a piece cargo - sandbags (refer with figure 3). Before testing, all bags were weighed. For each specific bag, a specific installation location was determined (refer with figure 2). The load was applied in approximately equal steps with an exposure time of 20 minutes. At each stage, readings were performed on instruments and an inspection of the state of building structures. Upon reaching the control load on stiffness and crack resistance, the shutter speed was 30 minutes.

**Figure 2.** General view of the loading area of the overlap of the first floor
Figure 3. The third cycle (3/4 of 30% of the regulatory load) load of the first floor ceiling area

As a result of the tests, the width of crack opening and vertical movements of floor slabs, grillage and displacement in the space of columns skeleton on the load steps and at the control load were determined. Control of vertical movements of the floor slabs and grillage was carried out by a high-precision electronic level Trimble DNI 0.3, the spatial position of the frame columns - by an electronic total station GTS-102N.

In order to identify the history of changes in the dynamic parameters of a building during the field tests with static loading at each loading stage, as well as after unloading, in accordance with [5, 6], the corresponding measurements of the period and logarithmic decrement of the fundamental tone of the natural oscillations of the building were carried out using a «Vibran 3.1» vibration analyzer ".

The relevance of measuring the dynamic characteristics of a building is quite well substantiated in the works [7, 5], and the book [8, 4] indicates that it is necessary to analyze and compare the natural oscillation frequencies of a real object during its operation.

Therefore, at each stage, 3-5 measurements were carried out by the instrument. The seismometer was placed on a hard horizontal surface in such a way that the arrow on the upper plane of the seismometer housing was oriented to the North. Since the amplitude of natural oscillations of a building grows with height, to increase the level of useful output signal, the seismometer was placed on the supporting horizontal structures of the upper part of the building, near the axis of the center of mass, namely, on the upper building landing (refer with figure 4).

Figure 4. Carrying out the measurements of the period and logarithmic decrement of the fundamental tone of the natural oscillations of a building with a four-channel vibration analyzer «Vibran 3.1»
The results of measuring the dynamic parameters of the building by the device were presented in tabular form and in the form of graphs (refer with figure 5).

![Graphs](image)

**Figure 5.** Frequency spectra.

a) along the Y axis; b) on the X axis; c) Z axis.

**Summary**

According to the field studies results, it was found that the cracks in the lower part of the floor slab are multidirectional, short-lived, shallow (depth up to 2-5 mm), and the nature of development indicates their shrinkage origin and they do not reduce the bearing capacity of the overlap. It was also found that the values of the parameters of the natural oscillation period of the ABC of a commercial building meet the requirements of [5], and their numerical values are similar to the data obtained in the information modeling of the building's spatial system using the Lyra CAD software package. The data obtained allowed the use of a well-known methodology for determining the residual life of a building [9] for a general assessment of the technical condition of a building, compliance with its regulatory requirements [9].

**References**

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