Integrated construction and technical structural analysis of the industrial buildings

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Abstract. The article presents a draft program of a comprehensive construction and technical examination of the industrial building structures. The features of the construction and technical examination of the industrial building structures are described. An algorithm of the sequence of actions for the technical examination of the object structures is developed. The measures to repair and restore the working condition of the damaged structures have been developed.

Introduction

Construction and technical expertise are an integral component of ensuring the quality, reliability and safety of buildings and structures. Any measures for the repair, reconstruction or dismantling of a building are carried out only after a full comprehensive technical examination of the building structures and utilities [1]. The construction and technical examination data analysis makes it possible to make a decision on the facility repair or reconstruction feasibility, to establish a list and the scope of restoration work, as well as their cost. Construction and technical expertise are also a tool for real estate management [2].

The purpose of the research work is the development of a comprehensive construction and technical examination of building structures, the determination of the technical condition category and the development of repair and restoration work.

The object of examination is an industrial building located in an existing building in the center of Rostov-on-Don. Estimated time of the construction - the end of the 60s of the 20th century. Structurally, the object consists of separate buildings built at different times and combined into one building. The need for construction and technical expertise is due to the prospect of building reconstruction due to a change in ownership and a change in the purpose of using the facility. It should be noted the lack of the design documentation for the facility, which made the examination complicated.

The inspection of the building structures was carried out in accordance with the requirements of regulatory and technical documentation [3].

During the examination, the following issues were assessed and recorded: layout plan and climatic conditions of the site, structural characteristics of the building, type of materials of building structures, qualitative and quantitative characteristics of the identified structural defects.
The examination technique included visual and instrumental examination based on a parametric approach.
To carry out the construction and technical examination, the following tasks were set and solved:
- the geo-radar studies were performed;
- the control measurements of structures were carried out;
- the building structures were examined in detail;
- the physical and mechanical characteristics of building materials (brick, concrete, mortar, etc.) were determined;
- the individual structures were calculated.
For a comprehensive and objective assessment of the inspected object’s condition, we developed a draft program of construction and technical expertise, which included:
- conducting geo-radar studies to establish the buried piles under the foundations of columns, loosening the soil and subsidence of the foundations;
- breakdown of the total area into the separate zones according to the main features: depending on the purpose (type) of the structures - foundations, columns, floor structures (beams, slabs), wall, roofing, etc.; depending on the features of operation - above the arched opening, above the open storage area, above heat sources, in areas of constant humidification, etc.; depending on the visual state of structures - with obvious defects and externally defect-free.
The main stages and composition of the expert procedures for a comprehensive construction and technical examination are presented in Table 1.

| Stage name                  | Composition of the expert procedures                                                                                                                                                                                                 |
|-----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Introductory stage          | Examination of the available technical documentation for the facility.                                                                                                                                                              |
|                             | Analysis of the geological, geophysical, climatic conditions of construction in relation to the object under investigation.                                                                                                |
|                             | Analysis of the conditions for the technical examination:                                                                                                                                                                             |
|                             | - access to structures;                                                                                                                                                                                                              |
|                             | - the need to install scaffolding;                                                                                                                                                                                                   |
|                             | - floor height and floor space;                                                                                                                                                                                                      |
|                             | - pitch columns supporting structures;                                                                                                                                                                                               |
|                             | - type of construction material;                                                                                                                                                                                                     |
|                             | - overall dimensions of structures.                                                                                                                                                                                                   |
|                             | Acquaintance with the state of structures based on photo report materials.                                                                                                                                                          |
| Preparatory stage           | Installation of temporary mounts to prevent the collapse of structures.                                                                                                                                                             |
|                             | Installation of scaffolds, scaffolding for inspection and repair work.                                                                                                                                                               |
|                             | Preparation and delivery to the facility (acquisition) of tools and instruments for visual assessment and non-destructive quality control and structural diagnostics.                                                                 |
|                             | Cleaning the surface of the examined structures’ elements.                                                                                                                                                                             |
|                             | Sampling, manufacturing of samples.                                                                                                                                                                                                 |
| Preliminary visual examination | Determining the height of each room.                                                                                                                                                                                               |
|                             | Identification of the type and material of load-bearing structures.                                                                                                                                                                 |
|                             | Identification and classification of defects and structural damage.                                                                                                                                                                  |
|                             | Drawing up the list of defects.                                                                                                                                                                                                       |
|                             | Compilation of a detailed structural inspection program.                                                                                                                                                                              |
| Detailed instrumental examination | Inspection of structures and registration of detected defects                                                                                                                                                                          |
|                             | Measurements, geodetic survey, measurement of the opening of cracks, deflections’ width;                                                                                                                                             |
|                             | Determination of actual structural characteristics by testing the selected
samples or non-destructive methods.

Assessment of the building structures’ technical condition.

Determination (calculation) of physical wear of individual structures and the building as a whole.

| The final stage | Preparing and executing the construction act and the technical examination of the inspected object (conclusions) |
|-----------------|------------------------------------------------------------------------------------------------------------|
|                 | Development of technology for repair work                                                                   |
|                 | Drawing up a calendar plan and a detailed (detailed) work program                                           |
|                 | Determination of volumes, terms and cost of repair and restoration work                                      |

In accordance with the developed program, a construction and technical examination was carried out, as a result of which a number of supporting structures were identified as defected, the inspection and repair (strengthening) of them should be carried out as quickly as possible. The condition of a number of structures is tentatively assessed as repairable - there are defects indicating a decrease in bearing capacity, but there is no threat of collapse. The state of such structures affects the rate of physical deterioration of the building as a whole, but after repair and restoration works, they can fully restore their initial operational characteristics.

The condition of some structures is assessed as unsatisfactory - there are defects indicating a decrease in bearing capacity, there is a threat of collapse, their dismantling and replacement is required. The conclusion about the impossibility of further operation of the structure is given according to the results of calculating the loss of the bearing capacity of the structure in the Ansis program software.

The conducted visual studies allowed to classify the defects and damage according to the criteria of significance (criticality), localization, the feasibility of repair or the need to replace structures.

A number of designs with identified defects are presented in Figure 1.

![Figure 1](image)

**Figure 1.** The defects and damage to the object’s structures

- a) peeling of the plaster layer of the ceiling plate;
- b) the defects in the plaster layer and the destruction of the ribs of the floor slab due to leaks of the roofing;
- c) destruction of the protective layer of concrete with exposure of reinforcement and traces of corrosion.

The structures with obvious defects affecting the safety during operation of the facility should be repaired or replaced as fast as possible, the subject to measures to ensure the safety of the repair work and prevent an accidental collapse of structures and their fragments.

Based on the results of a visual inspection of the structures of the warehouse, a list of defects of the supporting structures was compiled (Table 2).

**Table 2.** The object supporting structures defects’ list fragment.

| Type, characteristic of the defect | Repair Activities and restoration of structures |
|-----------------------------------|-----------------------------------------------|
| Floor and floor constructions      |                                               |
| Cracks in the slabs’ shelves, in some areas | Remove loose, damaged layers of concrete     |
with exposed reinforcement, violation of the protective layer of concrete, traces of the reinforcement corrosion.

| Structures, clean areas of damaged reinforcement. Restore the protective layer of concrete structures, repair structures |
| Cracks and delamination of concrete of longitudinal and transverse ribs due to reinforcement corrosion. |
| Mechanical destruction of concrete ribbed slabs with exposure of reinforcement. |
| Excessive deflections of individual continuous slabs are more than standard values. |
| Areas of wetting, peeling concrete slabs, due to leaks of waterproofing roofing. |

**Columns, connections**

| Lack of connection between the columns and brick walls is due to trimming during reinforcement of columns with metal structures. |
| Revision and restoration of connections between columns and brick walls. |
| Lack of corrosion protection of steel embedded parts and elements of columns and connections. |
| Perform corrosion protection of the embedded parts and the elements of columns and connections. |
| Destruction of concrete in certain sections of columns without exposure of reinforcement. |
| To clean the surface of the damaged areas from loose concrete, to clean the reinforcement from corrosion products (if necessary, restore reinforcement), to restore the protective layer of concrete with repair compounds that provide the necessary adhesion to old concrete and the strength of at least the actual concrete class in the structures. |
| Mechanical destruction of concrete in certain sections of columns with exposure of reinforcement. |

**Bearing walls**

| Vertical cracks on the walls of the building with a width of up to 15 mm. |
| Carry out repairs, repair cracks with repair compounds |
| Cracks in the adjoining zones of the new and old brickwork in the laid openings of windows and doors. |
| Perform anti-corrosion treatment of metal elements and embedded parts. |
| Local areas of the concrete protective layer destruction with exposure and surface corrosion of window lintel reinforcement. |
| Restore the protective layer of concrete slabs with repair compounds that provide the necessary adhesion to old concrete and the strength of at least the actual concrete class in the structures. |
| Flushing (weathering) of cement-sand masonry mortar and destruction of bricks in the basement of the walls, parapets and drainpipe locations. |
| Perform an audit and repair of the drainage system. Plaster the basement and damaged areas. |

We have proposed a general algorithm for the construction and technical examination (Figure 2), the principles of which are described in [4].
Figure 2. Algorithm for technical diagnostics and development of measures for the building structures working condition restoration

The algorithm includes the main stages, the composition of the procedures of which was previously described in the publications of authors and other researchers:

1. **Informaion Collection on the Object State**
   - Initial inspection of the facility, drawing up a list of defects and inspection programs
   - Visually - instrumental assessment of the defects’ characteristics in damage to the area
   - Instrumental assessment of physical and mechanical characteristics of an object
   - Establishing an object’s state category
     - I category
     - II-III category
     - IV category
   - Repair facility

2. **Repair Program Development**
   - The choice of type and method of repair
   - The choice of methods and techniques for assessing the quality of repair work
   - Establishment of criteria for assessing the quality of repair work

3. **Performance of Repair of the Object**
   - The choice of repair compounds
   - The choice of repair materials

4. **Assessment of Quality of Repair Works**
   - Visual
   - Instrumental

5. **Processing Results of Assessing Quality of Repair Works**

6. **Recovery Conclusion**
   - Object dismantling
   - Further facility operation
- identification of defects and structural damage [5];
- establishing the category of the object’s technical condition [6];
- development of repair technology: surface preparation of structures [7], selection of repair compounds and restoration of structural integrity [8,9].
- quality control of the repair work: establishing a criterion for assessing the quality of work performed [10]; verification tests and calculations [11].

Summary

Studying and understanding the methodological principles of construction and technical expertise allows the specialists to present a picture of damage and defects and outline a list of priority measures to restore the working condition of structures.

The methodology of construction and technical expertise presented by the authors can be applied in assessing physical deterioration and establishing the category of working condition of the building structures, including in the absence of design technical documentation for the facility.

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