Assessment and Inspection of the Technical Condition of Monolithic Reinforced Structures in Transportation Infrastructure Facilities

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Abstract. This article gives a short description of an inspection program for concrete and reinforced concrete structures and provides a survey of complex transportation infrastructure facilities on the basis of this algorithm. It contains data on the technical condition of monolithic reinforced concrete load bearing structures used in transportation infrastructure projects obtained by the authors from research reports on construction quality monitoring produced by the Scientific Research and Testing Center “MGSU STROY-TEST”. Generalization, systematization and analysis of the available data have identified typical damage zones for concrete and reinforced concrete structures. Research findings have identified the need for developing integrated quality assessment and forecasting methods that can be employed in monolithic construction to prevent accidents. These methods will enable evaluation of accident-related risks using the probabilistic logic approach, probability theory theorems and decision-making under uncertainty. Analysis of the causes of defects and damage in concrete and reinforced concrete structures in monolithic construction is today an urgent task. The scale of the problems of reliability and safety of buildings and structures caused by repeated errors in their production and operation, cause significant material damage, injury and death.

1. Introduction
Assessment and inspection of defects and damage in concrete and reinforced concrete structures throughout construction and control operations are currently a vital issue. Customers by and large lack sufficient information about particulars of operation and deficiencies of structures. Many of them seek to economize on structure monitoring and reduce the scope and volume of inspections thus diminishing the adequacy and credibility of results. Inspection of buildings and structures is primarily focused on the surface zone of structural sections that determines their protective properties. The
central part of sections, a crucial factor of the load bearing capacity of a structure, is not fully inspected [4]. Construction quality improvement requires an analysis of the nature of damage and deterioration of monolithic reinforced concrete structures and an efficient monitoring and forecasting approach to assessment of their condition [1].

With the passage of time, any building loses its initial technical and functional qualities, such as strength, reliability, stability, load bearing capacity, etc. Identification of causes for a premature wear-out of structures calls for development of rehabilitation activities for their functional properties and inspections of buildings and structures [2-3].

2. Materials and methods

Buildings and constructions, building constructions in which at preliminary inspection defects and the damages influencing their bearing capacity, rigidity and stability, on operational parameters, and after influences of natural or technogenic character intensity exceeding settlement bearing capacity of building designs are found are subject to detailed inspection.

Depending on the technical condition of buildings, structures and their construction structures, as well as based on the objectives, the composition of a detailed survey of the building is recommended to include the following works:

- familiarization with the results of the preliminary survey of the building or structure;
- clarification and detailing of defects and damages identified during the preliminary examination of the building;
- photographic images, producing accurate maps and records of defects and damages;
- establishment of actual loads and impacts on the building, establishment of calculation schemes with fixing deviations from the project;
- determination of strength and deformation characteristics of materials of the main bearing structures by non-destructive methods;
- determination of concrete reinforcement and carbonization depth in reinforced concrete structures;
- determination of the degree of corrosion of metal structures;
- excavation of test pits for examination of foundations of structures and the selection of soil samples for laboratory analysis;
- sampling of building structures for laboratory testing;
- calibration calculations of the bearing capacity of all building structures or the building as a whole;
- assessment of the technical condition of building structures;
- execution and execution of measurement works - floor plans, floor plans, roof plan, sections, facades, nodes;
- analysis of the results of a detailed survey of the building drawing up a conclusion;
- development of recommendations for elimination of identified defects; the development of components of building structures reinforcement.

In general, the conclusion on a detailed examination of the building and structure has the following composition:

- titled page with stamps and signatures;
- list of organizations and persons who participated in a detailed examination of the building, indicating the profile and qualifications;
- introduction indicating goals, objectives and scope of work for a detailed examination of the building;
- general information about the object - the history of construction and operation, climatic and hydrogeological conditions, time of the survey;
- description of the structural design of the building, space-planning decisions and identified deviations from the project;
- information about loads and impacts;
- description of defects and damages, indicating their characteristics and causes;
- assessment of the degree of damage and the category of technical condition of building structures;
- conclusions about the possible future operation of the building, recommendations for strengthening, restoring operational characteristics;
- conclusion on the results of a detailed survey of the building;
- completed drawings of measurements;
- card of defects and damages;
- photo materials;
- materials of verification calculations;
- materials of instrumental tests;
- laboratory test materials;
- developed amplification nodes;
- evidence

The technical condition of buildings and structures is inspected in three stages: preparation for an inspection; preliminary (visual) inspection; detailed (instrumental) inspection [1, 2].

The preparatory stage of works consists of familiarization with the object of inspection, its special layout and structural solutions, review of materials of engineering and geological surveys, obtaining and analysis of design documentation, and drawing up a work program with account of a statement of works agreed upon with the customer [1].

The next stage includes a preliminary (visual) inspection of the condition of structures. First of all, it is necessary to record defects and damage, draw up damage diagrams and charts, give details of their characteristics, and determine the degree of damage and the category of the structure’s technical condition [1, 5]. If the preliminary inspection reveals any defects or damage reducing the strength, stability or rigidity of the load bearing units of a building or a structure (columns, beams, floors, girders, etc.), a detailed (instrumental) inspection is held. A statement of work is developed, and tasks, objectives and scope of the detailed inspection are determined including, if necessary, a detailed inspection program. In general terms, a detailed inspection program for concrete and reinforced concrete structures can be described as a flow-chart shown in Figure 1.
Performing technical inspection of the building, also perform an assessment of the technical condition of concrete and reinforced concrete structures based on external characteristics:

- determination of geometric dimensions of structures and their sections;
- comparison of actual dimensions of structures with design dimensions;
- determination of the type and size of visible defects and deformations;
- determination of the General spatial position, type of construction and compliance with project documentation.
- verification of compliance of actual loads with design (their values and directions);
- determination of the state of protective coatings (paint, plaster, thermal insulation, protective screens, etc.);
- determination of wet areas and surface efflorescence;
- determination of the state of strength characteristics of the protective layer;
- determination of the presence of visible cracks and splinters of the protective layer;
- determination of the presence of visible violations of adhesion of reinforcement with concrete;
- determining the presence of visible corrosion of the reinforcement (at the exit to the surface of concrete corrosion of reinforcement in the spalling of the protective concrete layer, by controlling splitting off of the protective layer);
- determination of the presence of visible defects in concreting structures.

Performing technical inspection of the building, also perform an assessment of the technical condition of steel structures based on the assessment of the following factors:

- presence of deviations of the actual sizes of cross sections of steel elements from design;
- defects and mechanical damage;
- conditions of welded, riveted and bolted connections;
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- degree and nature of corrosion of elements and connections;
- deflections and deformations;
- strength characteristics of steel;
- the presence of deviations from the design position of the elements.

In the process of detailed inspection of structures, samples of concrete and reinforcement are selected for physical-mechanical and physical-chemical studies in the laboratory. Sampling sites are determined in the least stressed areas so that the load-bearing capacity of the structure is provided taking into account the weakening.

At the final stage, deskwork on the information collected and verification calculations are provided. The calculations are based on the results obtained during the technical examination, namely:
- visually visible defects in structures and deviations from the design dimensions;
- level of wear of structural elements and strength characteristics of materials;
- existing loads and real design patterns;
- atmospheric effects, soil precipitation, etc.

Verification calculations of building structures are carried out manually or using specialized computer programs. Construction and technical expertise in the form of a technical survey may also include thermal imaging research of buildings.

According to the measurement results, thermograms are compiled, and heat losses are calculated through the design of the fence.

The result of all the work carried out is a technical conclusion, consisting of a description of the construction site, the results of a detailed technical examination of the structural elements of the structure, a photo report of the identified defects, and the results of laboratory studies of materials.

The document consists of a calculation and graphic section. Thus, the customer is given a document with an objective assessment of the condition of all elements of the building and communication lines, the functionality of the building, the level of wear, hidden defects, as well as the possibility of reconstruction and further use for rental, sale, etc.

The technical condition of buildings and structures units should be determined by results of visual and instrumental inspections as well as laboratory testing and check calculation of their load bearing capacity [1, 5]. These works have been implemented using the database of Scientific Research and Testing Center “MGSU STROY-TEST” of the Moscow State University of Civil Engineering.

The development of evaluation methods for the technical condition of transportation infrastructure included visual and instrumental inspections of bridges, tunnels, overpasses, etc., conducted by the authors of this study.

The following instrumental measurements were carried out by the staff:

Strength of concrete and reinforcement structures. The strength of the concrete surface layer is determined by the methods of separation with chipping, chipping ribs, separation, plastic deformation and elastic rebound (GOST 22690).

The scope of the test should be taken:
- when assessing the strength of one structure or a separate area of the structure at least 3 sections in the design sections or in the area with reduced structural strength;
- when assessing the average strength of a group of similar structures at least 9 sites in the design sections of structures;
- when assessing the average strength and coefficient of variation of the strength of concrete of a group of similar structures at least 30 sites, if as a unit value is taken the strength of the concrete site or 9 sites (3 sites per structure), if as a unit value is taken the average strength of the concrete structure or its zone.

A detailed survey of the structure may not be made if the defects do not exist, deflection and crack widths do not exceed the allowable, size of section and reinforcement answer design, strength of concrete and reinforcement is not below the design. In this case, verification calculations are allowed to be performed according to the results of preliminary inspection and design data.
The visual inspection has revealed the following slab damage: penetration corrosion of superstructures; longitudinal cracks in bridge deck surfacing; transversal cracks; frost surface deterioration of the concrete protective layer; concrete deterioration accompanied by exposure of the reinforcement; soaking traces, etc. The most common damage of U-shaped girders is damage to longitudinal ribs including chipping, concrete deterioration, and reinforcement exposure and corrosion. Support structures contained deformational cracks, slab-to-slab connection cracks, and deterioration of the protective layer ac-companied by reinforcement exposure and corrosion [3]. The most hazardous type of defects called critical is damage that reduces the load bearing capacity of a structure. Such defects include cracks not permitted by the design, inclined cracks in beam walls, horizontal cracks in slab-to-span connections, branched cracks, etc. An evident sign of serious damage is frequent lateral cracks in the tension area of flexible elements made of ordinary reinforced concrete with openings in excess of 0.5 mm [4]. The most common damage of monolithic reinforced concrete floors is deterioration of the protective concrete layer of longitudinal and lateral beams with working reinforcement exposure and corrosion as well as deterioration of slab-to-slab connections and corrosion of inserts [7].

3. Conclusion

As can be seen from the above, the completed works of technical inspection of concrete and reinforced concrete structures make it possible to assess the current condition of the building’s structural parts, determine the operability of the structure, and identify defects with a view of eliminating the damage that threatens human lives and jeopardizes the safety of buildings and structures [5]. There is a need for developing methods of integrated evaluation and forecasting of the quality of monolithic construction operations for accident prevention purposes. Such methods of forecasting accident-free operation will ensure the safety and quality of operated buildings and structures. The design safety of a construction project is determined by the accident risk distribution law [7, 8]. Using its value, the degree of uncertainty of the technical condition of a load bearing unit of the building can be determined. The indicator’s dynamic curve testifies to the transition of a facility from one qualitative condition to another. Thus, a conclusion can be made on whether the facility has changed its condition from safe to an emergency or, for instance, from an emergency to a dilapidated emergency [6, 10, 11, 12].

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