Methodical approaches to destructive and non-destructive testing application in forensic construction and technical expertise

Inna Zilberova, *Irina* Novoselova*, *Tareq Neamah Mohsen* AL-Fatla, and *Konstantin* Petrov

Don State Technical University, 344002, Rostov-on-Don, Russia

Abstract. The article discusses the features of the destructive and non-destructive testing methods in the framework of forensic construction and technical expertise. Construction inspection of buildings and structures in the course of forensic construction and technical expertise is aimed at determining the characteristics of the actual technical condition, both of the structure itself and of its individual elements and structures. Conducting the objective and reliable research is not possible without accurate measurements, which necessitates the use of various methods, technologies, as well as modern devices and instruments.

1 Introduction

Forensic construction and technical expertise as a type of forensic engineering and technical expertise plays an important role in the investigation of events that have caused accidents, the occurrence of deformations or the appearance of hidden defects' external signs in the structures and construction objects' units [1].

Control is important at all stages of the life cycle of buildings and structures [2]. When inspecting a building in the process of construction and technical expertise, there are two main ways to control the quality of building materials, products and structures: destructive and non-destructive [3]. The main task of control is to ensure safety during the facility operation [4].

Destructive testing serves to quantify the maximum load, after which the destruction of the element under study occurs [5]. To ensure the safety and high quality of construction work, in many cases, non-destructive testing methods are used, the main tasks of which are to identify defects of various kinds, control the compliance of the work performed with norms and standards, check the reliability and identify the geometric characteristics of the object.

* Corresponding author: irina1000000@gmail.com

2 Research materials and methods

When carrying out a construction and technical examination, an important stage is to conduct the technical condition examination of the capital construction object under study, which, among other things, is carried out using various methods of destructive and non-destructive testing and the use of appropriate professional equipment [6].

The destructive method consists in identifying the limiting values of the building elements' bearing capacity, which implies bringing them to destruction. Along with this, destructive control gives accurate indicators of strength, stiffness, and density of the structure. The most effective destructive method is when testing the standard samples made of steel, concrete and other structural materials [7]. However, for real objects, the use of destructive control methods is not always expedient from an economic point of view [8].

Non-destructive testing methods can be applied directly at the facility, which at the same time remains operational without any damage. Conducting non-destructive testing makes it possible to draw up a conclusion on the reliability of the examination object, based on the data of its actual state. The use of non-destructive testing methods is most relevant when examining buildings and structures with a higher level of responsibility, as well as unique objects, including architectural monuments [9].

3 Results and Discussion

Destructive control is characterized by the fact that after its implementation, the suitability of the control object for further use for its intended purpose is violated. In this control, special samples should be taken, tested and measured for stresses, loads or deformations occurring in them. The ability to determine destructive loads and other characteristics that determine the operational reliability of an object based on the results of testing is the main advantage of destructive testing. In this case, the main disadvantage is that some objects (samples) are destroyed, and others are exploited in the future. Thus, the reliability of destructive control methods depends on the properties homogeneity in the samples taken for testing and in real objects, as well as on the similarity of test and operating conditions.

For the purpose of assessing and monitoring reliability, as well as individual properties of construction objects or their individual elements, non-destructive testing methods are actively used, which imply the implementation of measurements without damaging the objects of study and at the same time allow obtaining reliable characteristics of the parameters that determine the technical condition of the objects to be inspected. Nevertheless, non-destructive testing has quite significant drawbacks (Table 1). Despite this, in the course of the construction and technical expertise, objects of cultural heritage, as well as parts of buildings and structures, to which access is limited [10], will be examined. For these cases, non-destructive testing is the most optimal option, due to the fact that it does not require the destruction of the controlled element and provides for the possibility of further operation of the object. In addition, the use of non-destructive testing methods makes it possible to save material and time resources.

Table 1. Advantages and disadvantages of non-destructive testing.

Advantages	Disadvantages
Preservation of the continuity and surface layer of structures.	Quite complex, expensive equipment and qualified specialists are required.
The ability to repeat the same operations multiple times.	
The ability to measure at any number of available points.	The test results are not the value of the desired factor, but an indirect indicator

Small amount of time spent on testing. The ability to obtain not only strength, but also other data on the quality and condition of structural materials (defects, composition and structure, element thickness, crack depth, reinforcement location, etc.).	(the intensity of absorption of ionizing radiation, the ultrasound propagation speed, etc.). Therefore, in order to determine the numerical value of the desired parameter, it is necessary to identify the relationship between it and the indirect indicator, the determination of which can be difficult.

According to GOST R 56542-2015 “Non-destructive testing. Classification of types and methods "methods of non-destructive testing are combined into separate independent groups.

- Ultrasonic methods of non-destructive testing record and analyse the parameters of elastic waves that arise in the test object during vibrations with a certain frequency and amplitude. These methods include sound range and ultrasonic range methods. Ultrasonic methods are used to search for defects and check the quality of construction and installation works, as well as to determine geometric parameters in cases where access to an object is difficult, as well as to determine the physicochemical properties of materials and products made from them.
- Magnetic methods of non-destructive testing are based on the interaction of the controlled object with magnetic leakage fluxes. This group includes magnetic particle, magnetomyographic, induction and fluxgate methods.
- Methods by penetrating substances are based on the capillary penetration of a special luminescent substance into the cavity of the controlled object. An auxiliary substance is applied to the previously cleaned surface, then its excess is removed and the result is analysed. This group includes the capillary method, which is used to control surface, through defects and the leak detection method, which is used to check the weld joints.
- Eddy current methods are designed to detect surface and subsurface defects in metal structures and parts, control dimensions and vibration parameters, determine physical and mechanical parameters and structural state, detect electrically conductive objects, and also for solving other problems. Methods of scattered and reflected radiation are the main ones in this control group.
- The vibro-diagnostic method is based on the vibrations’ analysis of various frequencies and amplitudes that occur during the use of special equipment. This method is universal, because it makes it possible to control the object at any stage of construction, without stopping the technological process or operation.
- Electrical methods register and analyse the potential and capacitance of the electric field that affect the research object. Electrical methods are used to examine conductors and dielectrics. This group includes a variety of methods, the application of which depends on the defect or the desired parameter: spark, capacitive, parametric, thermal, electron emission and electrostatic powder.
- Thermal methods are based on measuring the intensity and gradation of thermal radiation from the controlled object. Temperature changes are measured remotely and locally. There are various thermal methods, which differ from each other in the way of obtaining information about the research object. The result of the control depends on the defect, since the measured thermal radiation changes due to the heat transfer processes taking place in the controlled object.
- Radio wave methods are based on the impact on the object of radiation generated by electromagnetic waves of the corresponding frequency and the analysis of the parameters of the electromagnetic wave. Radiation methods are divided into two groups: depending on the impacting wave (reflection, transmission and absorption) and

characteristics (amplitude, phase, object geometry and polarization). These methods are used to study the objects made of materials that do not damp radio waves.

- Radiation methods are based on the analysis of the results of exposure to penetrating ionized radiation. Their distinctive feature is the efficiency and unlimited size of the controlled object. Radiation control methods are used to establish the quality of weld joints, casting, assembly work.
- Optical methods are based on registration and analysis of optical effects associated with refraction, reflection and scattering of light rays by the surface or volume of the controlled object. This group includes methods based on the phenomena of diffraction and interference, which help to determine the microgeometry of solids, sphericity and defects of various origins.

When choosing a method of non-destructive testing, it is necessary to pay attention to such parameters of an inspected object as its physical and chemical properties, dimensions and thickness, the type of the object itself, as well as the cost of execution or another method [11].

The use of non-destructive testing methods in the practice of forensic construction and technical expertise is an opportunity without accurate measurements, which necessitates the use of non-destructive testing devices. Having the information on the basis of which physical device the device operates, the expert has the opportunity to determine which structure or element should be used to study.

The choice of the required method and, as a consequence, of the non-destructive testing device primarily depends on the parameters and investigation of the controlled object. Depending on the type of controlled object, non-destructive testing devices are divided into the following types:

- Devices designed to detect violations of the continuity of structural materials (cracks, delamination, cavities, etc.);
- Instruments used to determine the geometric characteristics of structures (pipe diameters, dimensions of rolled metal, wear rate, coating thickness, etc.);
- Devices used to determine the physical and mechanical and physical and chemical characteristics (inconsistency with the chemical composition, hardness, plasticity specified by the project);
- Devices designed for technical diagnostics (determining the possibility of occurrence) of various defects, in particular, changes in size, physical and mechanical properties, as well as violation of the products' continuity during operation.

The success of the non-destructive control methods' application in construction and technical expertise can be ensured only if the correct choice of methods and measuring instruments for each specific task. Taking into account the development of modern instrumental base for non-destructive testing, such a choice does not present great difficulties. Modern devices for non-destructive testing make it possible to determine not only external, but also internal defects of examined objects. With the help of non-destructive testing devices, the reliability of information about the examined object state is ensured and possible causes of failure are determined, which makes it possible to get an idea of the technical state of the object being inspected, including for the future.

As part of the research in the course of construction and technical expertise, the devices that have been verified in a timely manner are allowed. If a construction and technical study is carried out using an instrument base that has not passed the verification, but is subject to it, then its results will not be adequate evidence.

The non-destructive method is indispensable in mass quality control of building structures, in identifying the actual state of structures, assemblies and elements during operation and reconstruction [12]. It should be borne in mind that in connection with the

widespread use of the non-destructive testing method in the practice of construction and technical expertise, it is important to constantly update and improve the existing tools set.

4 Conclusion

Modern practice of forensic construction and technical expertise shows that often the subject of investigation and court proceedings are the events that have caused accidents, deformations or the appearance of hidden defects' external signs in structures and units of construction objects. Determination of the construction work quality is carried out using various methods of destructive and non-destructive testing. At the same time, non-destructive testing has many advantages, which consist in the absence of the need to destroy or dismantle the test object. Destructive and non-destructive testing within the framework of construction and technical expertise is carried out using modern equipment that gives an opportunity to accurately control the quality of construction and installation or repair work. Non-destructive testing devices make it possible to determine the characteristics and properties of building structures, which are necessary in the process of examination, directly at the place of its conduct. This opportunity not only reduces the time for the examination, but also increases the reliability and accuracy of the research.

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