Influence of Operational Factors on the Object of Concrete Strength Control of Reinforced Concrete Structures

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Abstract. When determining the strength of concrete in reinforced concrete structures by non-destructive methods, factors such as temperature, humidity and the stress-strain state of the structure can have a significant impact on the accuracy of the devices. The impact of these factors, which increases with increasing humidity, begins with the surface areas of concrete structures. Up to 75% of building structures are exposed to the destructive effects of atmospheric and industrial environments, of which concrete and reinforced concrete structures account for about 500 million m². The article considers the degree of influence of these factors on the accuracy of non-destructive testing devices when using various methods for determining the strength of concrete.

1. Introduction

In present regulatory documents of concrete strength of operated reinforced concrete structures given by three main groups of methods:

- mechanical;
- ultrasonic;
- based on samples, taken from structures.

First two methods related to non-destructive methods involve determining the strength of concrete directly on the object by fixing indirect characteristics and their interpretation by calibration dependencies. The third is laboratory testing of selected concrete samples with a destructive load.

Indirect characteristics of mechanical methods of non-destructive control are the value of rebound of the striker from the concrete structure (elastic rebound method); size of the indenter imprint on the concrete surface (plastic deformation method).

Energy and her change by striker and concrete surface interaction (shock pulse method), have a correlation with concrete density. The same correlation can be used in ultrasonic methods (through and surface sounding); in these methods the main fixing indirect characteristic by through and surface sounding is velocity of ultrasonic impulse distribution in concrete.

The main factors which defining the operated conditions of reinforced concrete structures is temperature, humidity and stress-strain state. Changes of these factors cause fluctuations in the pore...
space of concrete and its density, which effects on the objectivity of methods for non-destructive survey of its strength.

Regulatory documents [1,2] restrict the using of non-destructive survey methods of concrete strength by positive temperatures and regulate the methodology of constructing regulate dependencies if necessary to conduct survey at temperatures up to -10°C without taking into account the humidity of structures during survey, including in the conditions of phase transition of the liquid presented in the pore space of concrete.

The purpose of this work was to develop and test methods for examining underground reinforced concrete structures operated in an aggressive environment with difficult access.

The object of research is structures with difficult access for the use of non-destructive testing methods.

The subject of the research is to develop and test a method for examining underground reinforced concrete structures operated in an aggressive environment with difficult access.

Hypothesis. Increasing the reliability of information about the technical condition of building structures during non-destructive testing, taking into account:
- joint influence of temperature and humidity on the objectivity of concrete strength control of reinforced concrete structures;
- influence of the stress-strain state of the structure on the objectivity of concrete strength control of reinforced concrete structures;
- results of spectral-frequency analysis of underground reinforced concrete structures operated in an aggressive environment with difficult access.

2. Relevance
The structure and properties of concrete are subject to constant changes under the influence of the environment, which requires systematic monitoring of the current state of building structures made of concrete, reinforced concrete and prestressed reinforced concrete by evaluating the mechanical characteristics and other parameters that affect their durability. The accumulated experience in the operation of buildings and structures has shown that violation of the rules for the production of concrete structural elements, as well as errors in the preliminary assessment of environmental conditions or their sudden unexpected change lead to damage to concrete and destruction of building structures.

The impact of these factors, which increases with increasing humidity, begins with the surface areas of concrete structures. Up to 75% of building structures are exposed to the destructive effects of atmospheric and industrial environments, of which concrete and reinforced concrete structures account for about 500 million m². Globally, the damage amounts to more than 5 % of national income. One of the ways to reduce economic damage is to strengthen the fight against premature destruction of building structures of buildings and structures under the influence of aggressive agents.

To improve the effectiveness of fighting the destruction of building structures, a technical survey is performed, the objects of which are the foundation soil, structures and their elements, technical devices, equipment and networks. The examination allows to set the current valid technical condition of the building (structure) and its elements: to perform a quantitative assessment of actual performance quality of design (durability, thermal resistance, etc.) based on time changes.

3. The aim of the research
To evaluate the combined effect of temperature and humidity of concrete on the objectivity of methods of non-destructive testing of its strength. To evaluate effect of stress-strain state of concrete structures on the objectivity of methods of non-destructive testing of its strength.

4. Theoretical part
Experimental studies to assess the joint effect of temperature and humidity of concrete on the objectivity of non-destructive testing methods of its strength were performed for concrete classes
C8/10 and C20/25 by testing twin samples with dimensions of 10x10x10 cm, saturated to a humidity of W = 2 %, 7 % and 12 % (for concrete C8/10), as well as W = 3 %, 7 % and 9 % (for concrete C20/25) at temperatures T = -18°C, +5°C, +22°C and +40°C. Differentiated conditions were established by the time of water saturation of samples with subsequent preservation (to avoid moisture loss) and holding in a climate chamber with different temperature conditions. Operational control of the moisture content of the samples was performed by the electric method. The strength of concrete was determined by the shock-pulse method and the method of through sounding in conditions of uniaxial compression of samples with a load of ~ 1.0 t.

The results of determining the strength of concrete by the shock-pulse method in various temperature and humidity conditions are shown in figures 1 and 2.

As follows from the graphs, the increase of humidity and low temperatures have a significant impact on the readings of the device when determining the strength of concrete class C8/10, which is due to the compaction of the concrete structure due to the crystallization of water in the pores. The difference in the readings of the device, insignificant at low humidity and increases with its increase. Difference in instrument readings for conditions W=12 %, T= -18°C and W = 2 %, T = -18°C is 13 MPa, which is significant for concrete of this class.

For concrete class C20/25, overestimation of the device readings occurs at the maximum humidity W = 9 % and the lowest temperature T = -18 °C.

At low humidity and positive temperature, the deviation of the device readings is not so significant, because with a denser structure of class C20/25 concrete with a smaller volume of water-filled pores, frozen water less compacts the structure of the material. For the conditions of W = 9%, T= -18°C and W = 3%, T= -18°C the difference in strength values is 14 MPa.

Ultrasonic method is more sensitive to changes in humidity and temperature of concrete. The strength directly correlates with the velocity of the ultrasonic pulse depending on the density of the medium. Graphs of changes in the speed of the ultrasonic pulse in concrete classes C8/10 and C20/25 depending on different temperature and humidity conditions are shown in figures 3 and 4.
Figure 3. The dependence between ultrasonic speed, temperature and humidity for concrete class C8/10.

For concrete of class C8/10, a significant change in the speed of ultrasonic begins at a humidity of more than 7 % and a negative temperature: the difference for conditions W = 12 %, T = -18 °C and W = 2 %, T = -18 °C is 900 m/sec.

Figure 4. The dependence between ultrasonic speed, temperature and humidity for concrete class C20/25.

For concrete of class C20/25, the maximum change in the ultrasonic speed is recorded at humidity W = 9% and temperature T = -18 °C. The difference for the conditions of W = 9%, T = -18 °C and other W = 3 %, T = -18 °C, is 600 m/sec.

A significant overestimation of the readings of both methods was found only at maximum humidity and minimum (negative) temperature.

Laboratory tests to assess the effect of stress-strain state on the readings of non-destructive testing devices were performed on concrete samples of classes C8/10 and C20/25 at sorption humidity W = 2% and temperature T = +20 °C. The sample was placed under a press that produced its step loading (2, 5 and 7.5 tons for C8/10; 15, 30 and 45 tons for C20/25). At each stage, discrete strength determination was performed using shock-pulse and ultrasonic methods. The percentage of the load is taken in relation to the maximum load. The test results are shown in figures 5 and 6.
Based on the presented graphs, it can be concluded that the changes in strength readings when using the shock pulse method for concrete class C20/25 are insignificant and are within the strength class of concrete. For concrete class C8/10, the difference is more significant. The speed of the ultrasonic pulse is significantly reduced with increasing load for both classes of concrete, which may be due to the beginning of the formation of a pyramid of destruction and the gradual separation of the outer layers of concrete, accompanied by the formation of internal cracks in the structure of the material.

5. Conclusion
Analysis of the results of the research allows us to draw the following conclusions:
1. In order to increase the objectivity of concrete strength control by non-destructive methods, it is necessary to take into account (limit) the humidity of the operated reinforced concrete structure, along with the temperature factor;
2. Concretes with an increased strength class are less sensitive to fluctuations in humidity and temperature due to the denser structure of the material, which does not allow water frozen in the pores to have a significant effect on the readings of non-destructive testing devices;
3. The degree of loading of the structure during operation does not significantly affect the readings of non-destructive testing devices up to the boundary of cracking, beyond which the speed of the ultrasonic pulse in the concrete is sharply reduced, while the shock-pulse method is less affected by microcracks.

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