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Research paper

Structure material physic-mechanical characteristics accuracy determination while changing the level of stresses in the structure

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Abstract

The reliability and durability of building structures is largely connected with the determination of the physic-mechanical characteristics (PMH) of a concrete structure, their measurement (determination) is the most critical procedure. The process of measuring physic-mechanical characteristics materials is characterized by various errors, which are divided into gross, systematic and random. The influence of systematic errors is taken into account by using various kinds of calibration (or gauging) dependencies which use non-destructive testing devices. The analysis of the presented results shows that the reliability of the belonging of concrete of different series to one general aggregate is rather low. This meant that the application of tariation dependencies, graduated for concrete in one series, will lead to significant errors in the determination of PMH for concrete of other series. Therefore, to clarify the physicomechanical characteristics of materials, it is necessary to use data on the level of stress-strain state of the structure.

Keywords: *stress-strain state, physic-mechanical characteristics, non-destructive control.*

1. Introduction

To ensure the reliability of the buildings and structures in operation, objective information is needed on the technical condition of their supporting structures. All systems for assessing the performance of building structures of buildings and structures are based on the diagnosis of their condition. There are three levels of definitions: single, periodic and permanent (or monitoring).

The existing regulatory documents [1–7] regulate the strength and deformative characteristics of the material, which are used mainly in the design of structures. In this case, the normalized value was obtained on the basis of probabilistic-statistical processing and is characterized by a certain conditional value.

The most widely used methods for determining the PMH of a material are based on changing (deforming) a small amount of material, i.e. local area of the construction element. Existing methods for determining the strength and devices that implement them do not allow to adequately implement in practical use the dependencies between the parameters of the measured instruments and the material properties obtained in laboratory conditions. The inadequate interpretation is due to the fact that:

- dependencies used by devices are functionals of the type "indirect measured by the device value at a local effect – the value of the breaking load on a standard sample";
- the dependences obtained are obtained by interpolating the measurement results in laboratory conditions and, as a rule, do not take into account the peculiarities of the formation of the structure of the structure material and take into account the change in the material properties of the structure over time;
- the accuracy of measurements is influenced by the physico-mechanical characteristics of the contact zone in the interaction between the "device – concrete", the formalization of the parameters of such a zone by the current nom is not sufficiently carried out.

2. Main body

The main result of the expert's work is to obtain information about the bearing capacity of structures, their reliability and durability, then obtaining information about the "strength of concrete" of a structure can be considered as clearly non-sufficient. Since the determination results are influenced by several other factors, information about which is necessary for the calculation of reliability and durability, the construction of a method for obtaining this information, as well as its hardware support, is an actual task.

Consider the necessary conditions for the construction of such a technique.

In order to carry out verification / verification calculations, information is needed on the geometric parameters of the construction, the properties of its constituent materials and the loads acting on the construction or assumed to act on it.

The scheme of operations for the implementation of the calibration calculation is shown on Fig.1.

Such a scheme could be successfully implemented under the assumption that the methods for determining the physic-mechanical characteristics of concrete are insensitive to the level of stresses in the structure and, moreover, the parameters of concrete are the same for the whole structure.

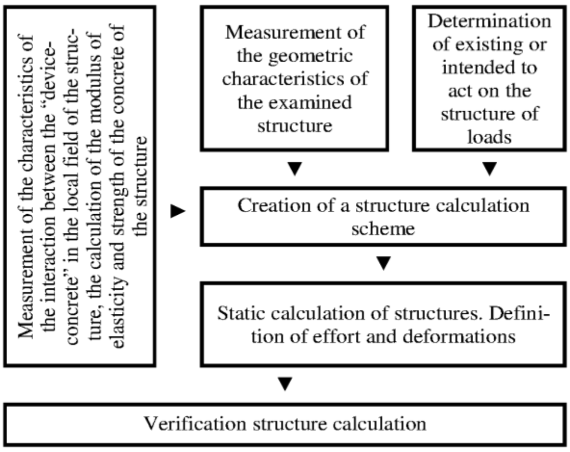

Fig. 1: The scheme of operations for the implementation of the calibration calculation using the results of determining the strength of concrete methods of non-destructive testing

The realized properties of the material of construction, as a rule, differ from the design values due to a number of circumstances. Such a difference may be related both to the technology of concrete mix production and the production technology works for concrete concreting, as well as to the operating conditions of the structure and the level of stress-strain state (SSD). Since the assessment of the reliability and durability of building structures is largely connected with the determination of the physic-mechanical characteristics (PMH) of a concrete structure, their measurement (determination) is the most critical procedure.
To determine the PMH of concrete, most researchers use non-destructive control (NC) methods [7–13].
The process of measuring PMH materials is characterized by various errors, which are divided into gross, systematic and random. If the use of mathematical statistics methods allows to eliminate gross errors, and the use of probability theory reduces the effect of random errors, the influence of systematic errors is taken into account by using various kinds of calibration (or gauging) dependencies which use non-destructive testing devices (NC). In this case, depending on the method of conducting, more than one systematic error can affect the measurement results. This meant that the result of each measurement can be represented in the form of a certain sum, one of whose components is a functional that reflects the dependence of the measurement result from systematic errors.
Consider the factors determining the properties of concrete in the structure and, therefore, affect the magnitude of the error.
Initially, the properties of concrete are laid during the preparation of the concrete mix. On Figures 2 and 3 are shown the results of tests of control concrete cubes of several series at the age of 28 and 90 days.

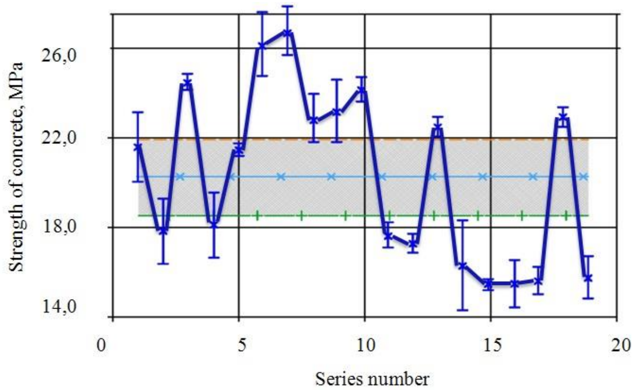

Fig. 2: Results of statistical processing of durability of concrete at the age of 28 days:

1 – change of strength values of concrete in series; 2 – average strength of concrete construction; 3 – the upper limit of the confidence interval; 4 – the lower limit of the confidence interval

Concretes of these series are prepared on the same components with their equal ratio. Under the series of concrete refers to concrete made within one shift. The difference in terms of concrete production is 28 days. The design was carried out under the assumption of "homogeneity" of the concrete structure.
By homogeneity of concrete in this case we understand the belonging of different series of concrete mixes of one general population, the PMH of which is determined by the building project.
The analysis of the presented results shows that the reliability of the belonging of concrete of different series to one general aggregate is rather low. This meant that the application of tariation dependencies, graduated for concrete in one series, will lead to significant errors in the determination of PMH for concrete of other series.

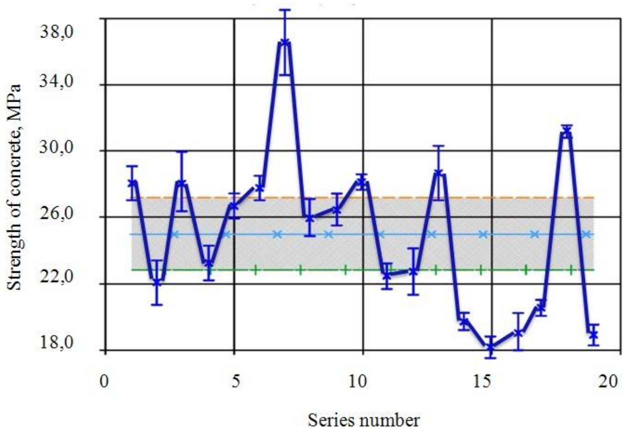

Fig. 3: Results of statistical processing of concrete strength at the age of 90 days:

1 – destination strength of concrete in series; 2 – average strength of concrete construction; 3 – the upper limit of confidence interval; 4 – the lower limit of confidence interval

Let's consider how the concrete technology affects the ability to determine the PMH of concrete in the construction.
Considering that the age of concrete is a significant factor influencing the strength of concrete, an object was chosen for the study, concrete work on which was carried out more than two years ago, and construction in general was incomplete for a number of reasons. The finishing works were not performed, which provided free access to the surface of reinforced concrete monolithic structures.
Reconstruction of the building (Fig. 4) is carried out by completing the construction of a reinforced concrete four - five-story monolithic carcass with a staircase.

Fig.4: Reinforced concrete monolithic frame of the reconstructed building.

The measurements were carried out above and below the level of overlap, since In these levels, visual inspection revealed the presence of concreting joints (Fig. 5).

Fig. 5: A fragment of a reinforced concrete frame of a reconstructed building

Figure 6 shows the scheme of measurements (zones in which the measurements were made are pointed). The lack of data for two columns at some points is due to the fulfillment of safety requirements in the conduct of research.

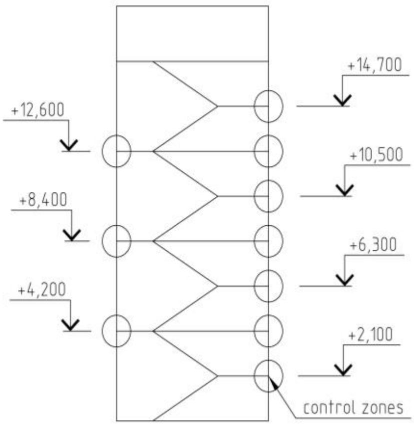

Fig.6: Layout of the zones of concrete in which measurements were taken.

On fig. 7–10 the results of determining the strength of concrete in the construction of a column of a multi-storey building are presented at the stage prior to the loading of the structure with the operational load. The given results show that the dependence of the results of the determination of PMH of concrete on the height of the column is not linear and reflects the features of the concrete technology, which manifests significant differences in the properties of concrete in the construction.

It is necessary to pay attention to the sharp change in strength values within the intervals of 10.3–10.7; 12.4–12.8; 14.5–14.9 m. Comparing the results of strength determination with a visual inspection, it was established that such a drastic change in strength can be explained by the peculiarities of laying and hardening the concrete in the structure. So in this case, the reliability of the concrete belonging to different series to the same general population is rather low. This meant that the strength of concrete, as well as the deformative properties associated with it, are different in different parts of the structure. Therefore, the use of calibration dependencies, calibrated for concrete in any one area of the structure, will lead to significant errors in other areas of the structure.

When loading a construction, differences in the level of stresses also affect the results of the readings of the NC instruments. After loading the construction with an operating load, the stresses appear that can exceed the stresses caused by the own weight of the structures by an order of magnitude, which also has a significant impact on the results of the determination by the NC methods.

To take into account the above-mentioned effects, an attempt was made to build a generalized calibration dependence. The study was performed on samples of concrete of six different compositions. To study the stated assumptions of the measurements, concrete cubes 100x100x100mm and concrete prisms 100x100x400mm were used.

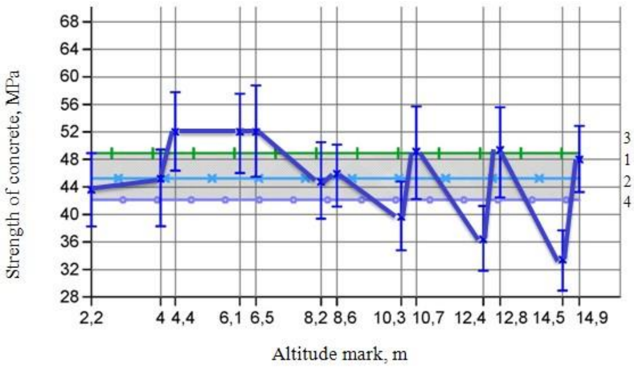

Fig. 7: Results of statistical processing of concrete strength of a column 1: 1 – change of strength values of concrete in height; 2 – average strength of concrete construction; 3 – the upper limit of the confidence interval; 4 – the lower limit of the confidence interval

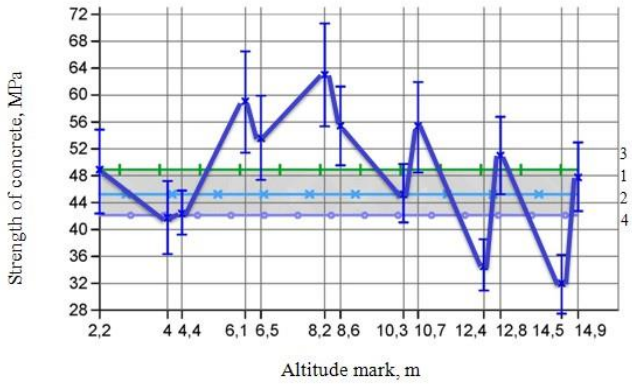

Fig. 8: Results of statistical processing of concrete strength of a column 2: 1 – change of strength values of concrete in height; 2 – average strength of concrete construction; 3 – the upper limit of the confidence interval; 4 – the lower limit of the confidence interval

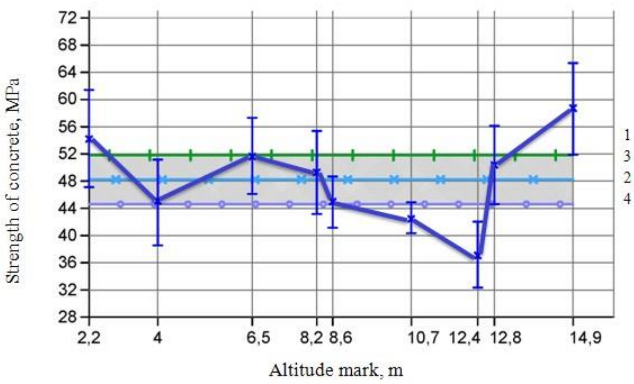

Fig. 9: Results of statistical processing of concrete strength of a column 3: 1 – change of strength values of concrete in height; 2 – average strength of concrete construction; 3 – the upper limit of the confidence interval; 4 – the lower limit of the confidence interval

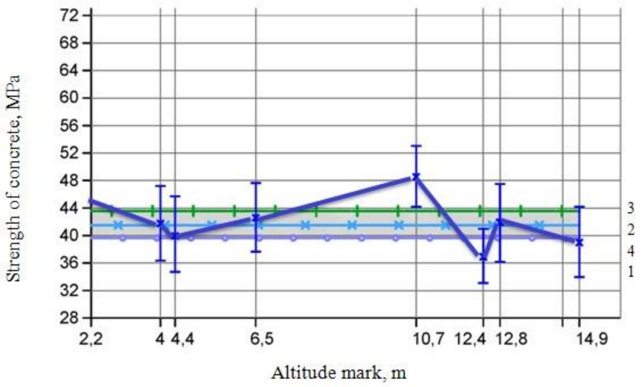

Fig. 10: Results of statistical processing of concrete strength of a column 4: 1 – change of strength values of concrete in height; 2 – average strength of concrete construction; 3 – the upper limit of the confidence interval; 4 – the lower limit of the confidence interval

The determination of the strength of concrete samples by non-destructive method was made. For the determination, a sclerometer was used that implements the method of elastic rebound (according to [4]). The determination was carried out at a different level of load applied to the test specimen with the subsequent determination of the strength of concrete on a P 125 press.

On fig. 11 presents the results of the construction of calibration dependencies for use by instruments of NC implementing a shock-pulse method.

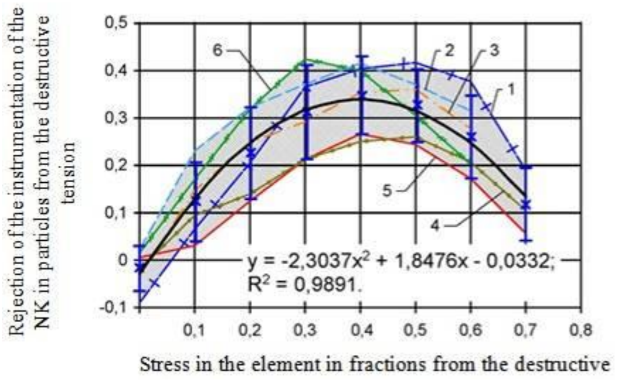

Fig. 11: The results of building of tariation dependencies for determining the strength of concrete by NC devices at different levels of SSD design for different compositions of concrete

1–6 – tariation dependencies for different compositions of concrete

3. Conclusions

The results of the study are in good agreement with the data of other studies [14–21]. However, during non-stationary effects on the structure, the intensity of mutually competing processes of structure formation and destruction can significantly change the PMH distribution in the concrete of the structure. Taking into account a priori accepted, when drawing up a design diagram, the uniform distribution of such properties, such temporary changes can provoke a chain reaction of SSD changes with the subsequent transition of the structure to a state unsuitable for normal operation or even an emergency one. At the same time, for massive structures, it is necessary to take into account that the realized PMH values may differ from the design ones even without taking into account the influence of temporary and operational factors. In accordance with accepted methods in the production of concrete mixtures, the parameters of intra-serial variability are controlled. An assessment of some arrays of information on the strength characteristics of concretes of especially important structures showed that the coefficient of variation of such a sample is 20–30% higher than the maximum possible standardized value. Those for some designs, it is necessary to reduce the guaranteed strength with a security of 0.95. At the same time, in-series parameters show compliance with the standard and project requirements. Assessment of the real state of the structure in this case requires the determination of the PMH of the material and the verification calculations.

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