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КОМПЛЕКСНЫЕ ИССЛЕДОВАНИЯ БЕТОНА НЕРАЗРУШАЮЩИМИ МЕТОДАМИ

COMPLEX STUDIES OF CONCRETE BY NON-DESTRUCTIVE METHODS

Аннотация. В данной статье рассмотрены неразрушающие методы определения прочности бетона, описан и представлен анализ результатов исследований двух методов испытаний – бурового и ультразвукового. Комплексные испытания этих методов позволяют предположить дальнейший характер поведения материалов и конструкций под действием нагрузок по сравнению со случаем, когда используется только один метод испытаний.

Abstract. This article discusses non-destructive methods for determining the strength of concrete, describes and presents the results of studies of two test methods - drilling and ultrasonic. Comprehensive testing includes studies on the choice of characteristics of materials and structures in comparison with the case when only one test method is used.

Ключевые слова: Испытания бетона, Прочность, Неразрушающие методы, Деформативность, Прочность.

Keywords: Concrete testing, Strength, Non-destructive methods, Deformability, Durability.

Introduction

A method for determining the strength of stone materials by the method of local destruction, for example, by drilling or sawing, is under development. Proposals for the implementation of this method are known, separate instances of devices are created [1, 2]. However, this method is not used in practice. This is mainly due to two reasons: first - difficulties with the cutting tool; the second - a small number of studies and the ambiguity of an indirect characteristic used to determine the strength of stone material [3-7].

In case of local destruction by drilling, usually fix the speed of rotation of the drill, the pressing force, the duration of drilling, while measuring the drilling depth. But for heterogeneous stone materials, such as concrete, fixing these values presents significant difficulties [8-14]. Therefore, in order to improve the control of concrete strength by the method of local destruction, a number of experimental studies were planned.

Conducting research

The studies were carried out on cubes with an edge of 10 cm, made of concrete with a composition of cement: sand: crushed stone = 1: 1,5: 2,25 on crushed stone grade 300, crushed stone with a grain size of 5-20 and river sand. Three series of experiments were carried out with concretes differing only in the water-cement ratio

(0,3; 0,4; 0,5). In each series, 30 concrete cubes were made, three prisms 10x10x40 cm and 6 cubes from the same mixture sifted through a sieve No. 5. The cubes hardened in sawdust for 7 days and 2 months in the open air.

The research methodology provided for:

1. Determination of the immersion depth of a ball with a diameter of 15.4 mm, poured into concrete using a press. Loading was carried out in steps of 500 N with complete load release at each step with determination of residual deformations.
2. Determination of the diameter of an imprint of a ball with a diameter of 15.4 mm, obtained after the ball is pressed in, as well as after impact on concrete, performed using a Borovoy sclerometer.
3. Determination of the transit time of ultrasound during sounding through the cube using the UK-15P device.
4. Determination of the immersion depth of a diamond drill with a diameter of 10 mm at various pressing forces. The power of the drill was equal to 1.5 kW, which to some extent fixed the rotation speed, the drilling duration was 5 seconds.
5. Determination of the cubic strength of concrete, the tensile strength of concrete during splitting, the prismatic strength of concrete, the modulus of elasticity of concrete and its density.

Table 1

The results of the study of W / C on the strength
and deformation characteristics of concrete R_b, R_t, E_b, ρ

W/C	**0,3**	**0,4**	**0,5**
R_c, **MPa**	27,5	10,9	5,6
R_b, **MPa**	23,1	8,0	4,8
R_t, **MPa**	1,33	0,65	0,48
E_b x10^{-3}, **MPa**	25,0	14,5	7,2
ρx10^{-2}, **kg/m^3**	24,2	22,7	21,8

The technique involved a random selection of cubes for each test series. Each type of test was subjected to 10 cubes. Impact, indentation and ultrasonic tests were carried out in accordance with the existing Code.

The results are shown in Figures 1-7 and in the table 1. The data presented were obtained by averaging the experimental results with a reliability of 0.9. As the analysis of the data obtained for widely used methods for determining the strength of concrete shows, the obtained curves coincide with the calibration curves used to control the strength of concrete (Figure 5, item 1 and Figure 7). Research results directly related to drilling, are shown in Figures 2 and 3.

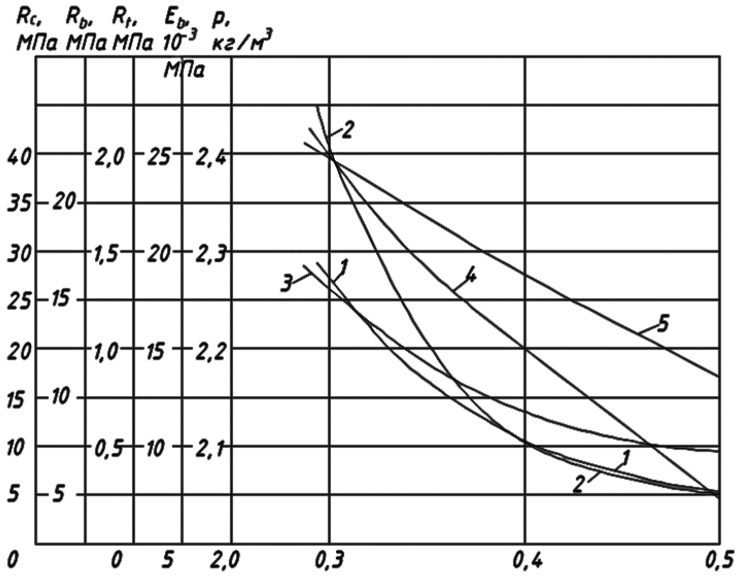

Fig. 1. Dependences of concrete cube strength R_c,

prismatic concrete strength R_b, concrete tensile strength R_t, elastic modulus E_b, concrete density ρ on the water-cement ratio: 1 -R_c, 2 - R_b, 3 - R_t, 4 - E_b, 5 – ρ.

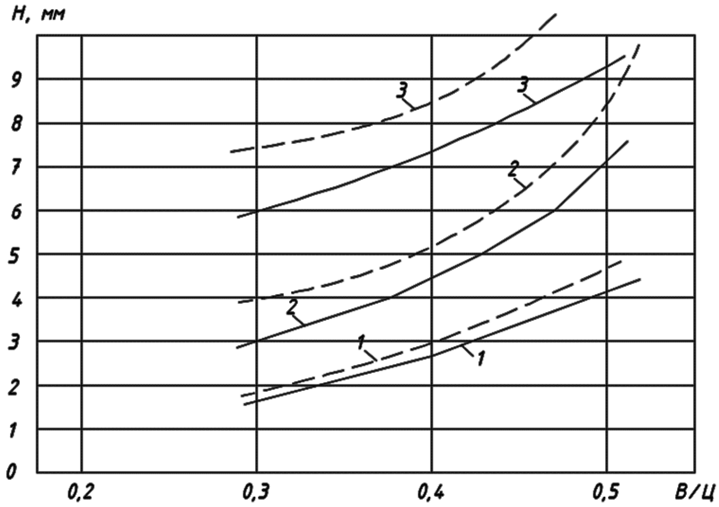

Fig. 2. Drill immersion depth versus water-cement ratio for pressure:

1 – 263; 2 – 409; 3 – 505 N / cm^2; - concrete, -------- – solution.

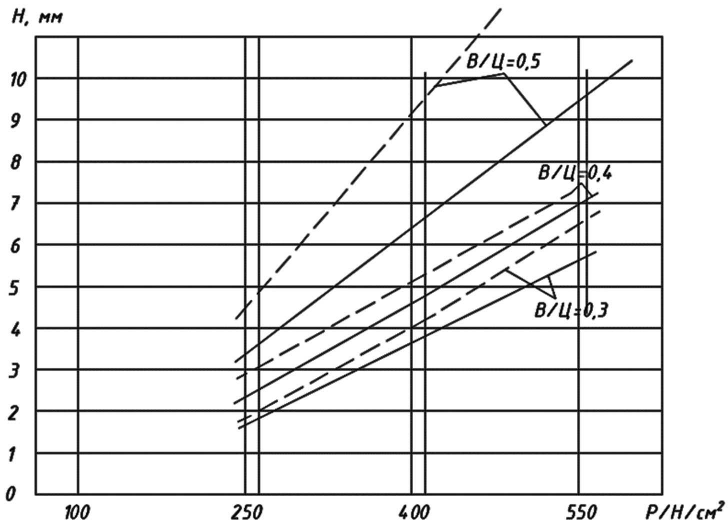

Fig. 3. Drilling depth versus drill pressure; - concrete, -------- – solution.

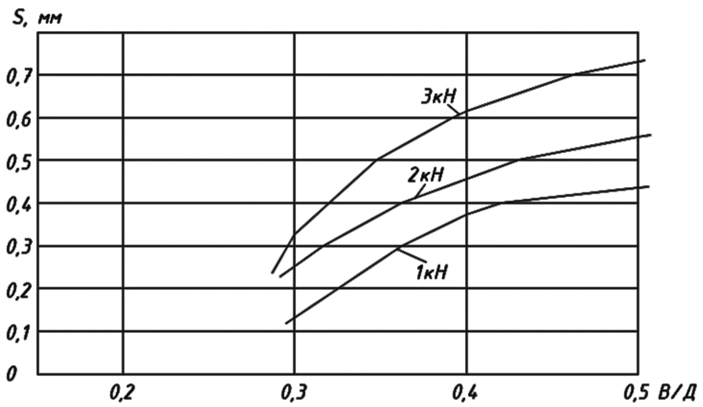

Fig. 4. Dependence of the immersion of the ball during its indentation by different forces on the water-cement ratio.

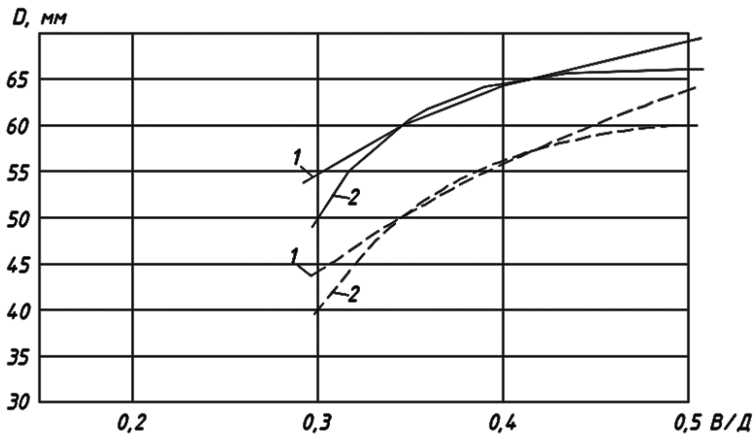

Fig. 5. The dependence of the ball imprint on the water-cement ratio:

1 - concrete samples; 2 - mortar samples; - immersion of the ball by blow;

--------- – mortar samples.

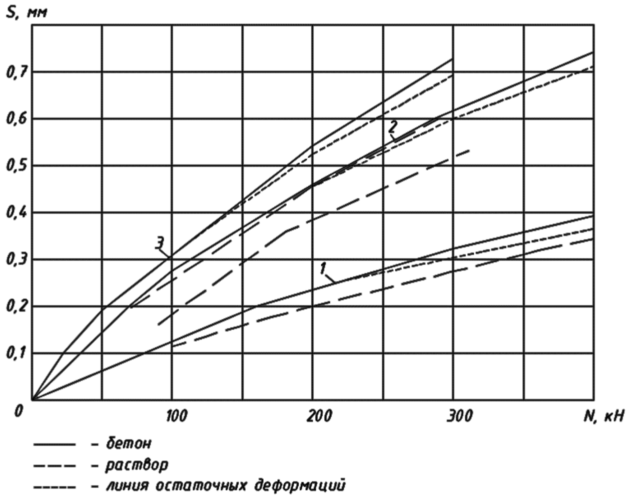

Fig. 6. Dependence of the depth of immersion of the ball on the indentation force: 1 - W / C = 0.3; 2 - W / C = 0.4; 3 - W / C = 0.5, where: бетон – loaf, раствор – solution, линия остаточных деформация - line of residual deformation.

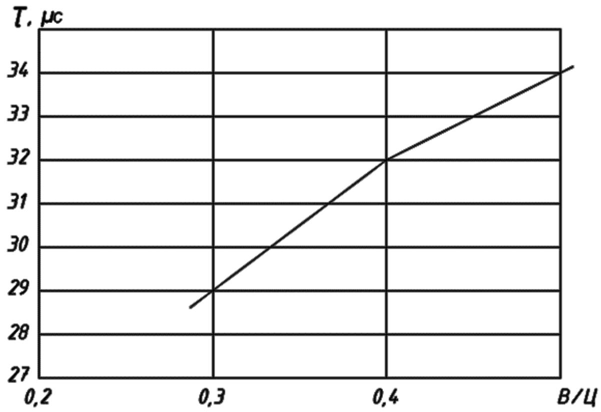

Fig. 7. The transit time of ultrasound through a concrete cube.

As can be seen from the figures, coarse aggregate affects the position of the curves "strength - drill penetration depth", but does not change the nature of the curves themselves. This criterion can be used as a first approximation, but this criterion cannot play a leading role. It would be more correct to directly measure the work going to local destruction. The insufficient volume of tests does not allow recommending the obtained dependencies for direct use. But the studies carried out make it possible to have a basis for further study of the method of local destruction and to reveal some of its connections with the known methods for determining the characteristics of stone materials. It is recommended to use the method of local destruction in conjunction with other methods for a more accurate determination of the strength of concrete or for a comprehensive determination of the strength and deformation characteristics of materials.

One of the ways to save raw materials and energy resources is the introduction of non-destructive testing at precast concrete factories as an integral part of comprehensive quality control.

The use of the ultrasonic method is regulated. It is a widely used method for controlling the strength of concrete. The method is based on the relationship between the strength of concrete and the speed of propagation of ultrasound.

In the theory of elasticity, it is established that the speed of longitudinal waves is associated with the characteristic of the deformability of the material - the dynamic modulus of elasticity Eg - by the functional dependence.

Using the ultrasonic method, it is possible to determine the dynamic modulus of elasticity of concrete, which is in a certain correspondence with the static Eст. As follows from literary sources, Eg exceeds Eст by 10-15% [13]. The value of Eст is necessary for verification calculations of the stiffness of structures for results of their loading tests carried out before the development of a new type of structures in production, as well as when changing the manufacturing technology, replacing materials, reinforcement, etc. determination of Eст takes quite a long time and requires the manufacture of samples - concrete prisms. The values Eg of using the ultrasonic method can be determined both on samples and in structures. To do this, it is necessary to determine the value of the velocity Vwr, m / s during through sounding by the formula 1:

$$V_{\text{скв}} = \frac{l_{sq}}{\tau} \cdot 10^4, \quad (1)$$

Where lsq - measurement base (end-to-end), cm;

τ – time of passage of the front of the first arrival, μs.

In structures, the speed value is set by averaging the measurement results in several of its defect-free areas.

The value of the dynamic modulus of elasticity (MPa) is determined by the formula 2:

$$E_g = V_{скв}^2 \frac{\rho \cdot 10^{-3}}{К \cdot 981}, \tag{2}$$

where ρ is the density of concrete, g / cm^3;

К - coefficient determined by the formula 3:

$$К = \frac{1-\mu_g}{(1+\mu_g)(1-2\mu_g)}, \tag{3}$$

where μ_g is the dynamic Poisson's ratio.

The value of μ_g is taken depending on the age of the concrete:

0,28 - 1-3 days after heat treatment;

0,22-28 days or more after treatment.

To confirm the theoretical conclusions, an experimental determination of the static and dynamic moduli of elasticity of samples of prisms 10x10x40 cm, made of heavy concrete, was carried out. The static modulus of elasticity was determined in accordance with GOST 24452-80 on an MS-1000 press. E_g was determined using an ultrasonic device UK-14P according to the method proposed by the implementation bureau of NIISK of the USSR State Construction Committee[13]. The results of the experiment are presented in table 2.

The given data confirm the assumption that the excess of $E_g$over $E_{ст}$ reaches 10-15% [12,13].

Table 2

Test results of samples - prisms.

Concrete class	**Coarse aggregate type**	**Static modulus of elasticity, $E_{ст}$, MPa**	**Dynamic modulus of elasticity, E_g, MPa**	$\frac{E_g - E_{ст}}{E_g}$ **10**
B20	Breakstone	30000	31849	58
B20	Gravel	26539,5	28782	7,0
B15	Breakstone	29666,7	30883	3,9
B15	Gravel	29816	30425	2,0

The next stage of the work was to determine the strength characteristics of concrete structures using a complex of non-destructive and destructive methods. At the KPD plant of the «Magnetostroy» trust, floor slabs were examined at the age of 1 day after heat and humidity treatment. Determination of the dynamic modulus of elasticity of floor slabs was carried out with an ultrasonic device UK-14P. The strength of these structures was determined with the Kashkarov reference hammer. At the same time, the cube strength was monitored on samples of 10x10x10 cm in size. The results are shown in Table 3.

Table 3

Results of determining the strength characteristics of floor slabs.

Test No.	Dynamic modulus of elasticity, E_g, MPa	Kashkarov's standard hammer strength, $R_{мол}$, MPa	Cubic strength, $R_{куб}$, MPa
1	18285,3	18,6	18,1
2	18628,3	17,9	18,1
3	16084,3	18,4	17,2
4	15341,0	16,8	17,2
5	16457,6	18,5	19,6
6	18303,0	16,8	17,8
7	15785,6	18,0	19,0
8	18821,7	16,6	17,0
9	21436,9	20,6	21,0

Results

The test results confirm the existence of a relationship between the strength and deformation characteristics of concrete. Obviously, with an increase in strength, the modulus of elasticity also increases. For example, in the course of test No. 4, the minimum strength characteristics of the floor slab were obtained: the cube strength was 17.2 MPa, the strength against the reference hammer was 16.8 MPa. At the same time, the dynamic modulus of elasticity is also minimal - 15341 MPa. During test No. 9, the values of strength obtained by destructive and non-destructive methods reached a maximum and amounted to 21 and 20.6 MPa, respectively. The dynamic modulus of elasticity is 21436.9 MPa and is the highest in this series of tests. In addition, the magnitude of the modulus of elasticity makes it possible to judge the degree of influence of force deformations on the elastic properties of a structure. The higher the modulus of elasticity, the better the elastic properties of the concrete.

The analysis of the results obtained gives a more complete picture of the strength properties of the structure, of its further behavior under the influence of loads in comparison with the case when only one test method is used [14-21].

Conclusion

Thus, the introduction of new methods of integrated control of building products and structures allows you to save material and labor resources due to the efficiency of carrying out field tests.

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