Modernization the system of periodic control for the concrete properties

Viktor Kolokhov[1*], and *Vasyl* Bilyk[1]

[1]Prydniprovska State Academy of Civil Engineering and Architecture, Technology of Building Materials, Products and Structures Dept., 49005 Architect Oleh Petrov Str. 24-a, Dnipro, Ukraine

Abstract. Periodic control of concrete properties is based on the use of non-destructive methods. Periodic monitoring of the condition of structures often is performed using ultrasonic devices. The accuracy of determining the physical and mechanical characteristics (FMC) of concrete depends on a significant number of factors affect. This reduces the accuracy of the results by standard methods. Based on previous studies, the methodology for using ultrasonic non-destructive testing devices was improved. The research and verification of the improved methodology in a real building demonstrate the low complexity of the work and sufficient reliability of the results. Improvement of the algorithm for work and data processing will allow to offer a reliable methodology for determining the technical condition of the operated structures and for periodic monitoring the concrete properties. A methodology for periodic monitoring of concrete properties in structures has been developed. It is necessary to carry out.

1 Introduction

Periodic control of concrete properties is an important component of the system:

- assessment of the technical condition of erected, repaired or reconstructed objects;
- control of the object technical condition in the process of planned or extraordinary inspections;
- technical inspections (expertise) to determine the state of damaged structures and accidents during operation.

Usually, such control is based on the use of non-destructive control methods [1, 2]. Papers [3-7] show that the ultrasonic method for determining the physical and mechanical characteristics (PMC) of concrete has significant uncertainty. This is largely due to the heterogeneity of concrete PMC and the parameters of the application method. Our own experience in assessing the technical condition of buildings and structures using non-destructive testing devices and our own laboratory studies [3-7] suggest that the current methods of using non-destructive testing devices need to be improved, as they do not take into account some influencing factors. In addition, the accuracy of determining the PMC of concrete when using ultrasonic devices for periodic monitoring of the structures condition is reduced.

* Corresponding author: kolokhov.viktor@pdaba.edu.ua

The purpose of the work. Improvement the method of using ultrasonic devices for periodic monitoring of the state of structures and verification of the improved method of controlling the properties of concrete by ultrasonic devices in a real object.

2 Results

The influence of the stress level in the structure and the orientation of the line along which the ultrasonic vibration (USV) propagation time is measured in relation to the line of principal stresses in the structure is investigated in paper [3, 6].

Figure 1 shows the dependence of the ultrasound speed on the relative stress level in the structure and the orientation of the line along which the ultrasound propagation time is measured in relation to the line of main stresses in the structure [3].

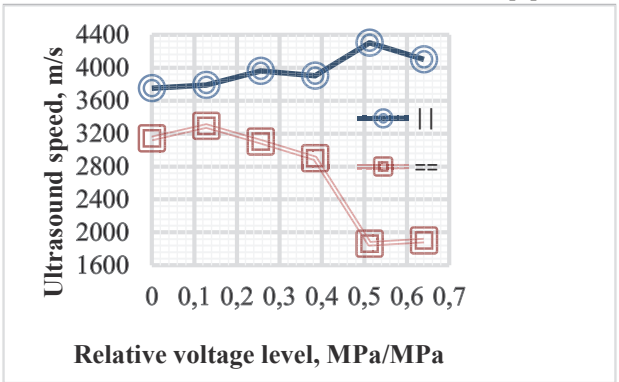

Fig. 1. The addiction of the "ultrasound speed - the voltage level in fractions of the destructive". The measuring device is located: in the vertical plane - ||; in the horizontal plane - ==

Figure 2 shows the results of ultrasound velocity measurements in four zones on the side surface of a reinforced concrete pillar. Control zones are located at a level of 1.4-1.7 m from the ground surface. Four series of measurements were carried out in each zone [6].

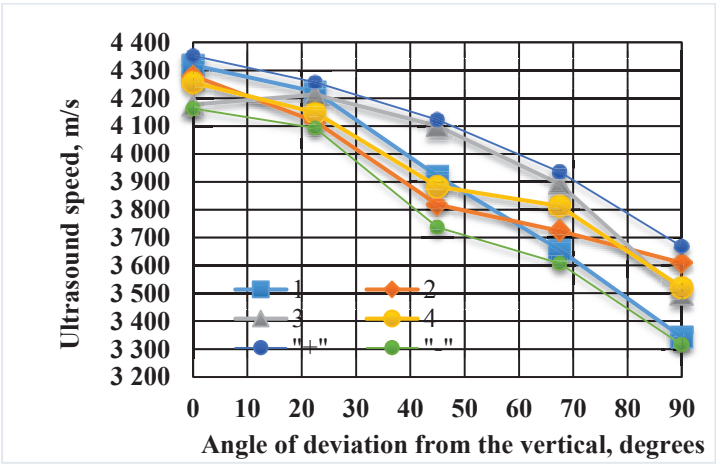

Fig. 2. Dependence "Speed of ultrasound - angle of deviation from the vertical of the device" for reinforced concrete racks: 1 - 4 - No. of the measurement zone; "+" and "-", the upper and lower bound of the confidence interval, respectively

The influence of the pressing force of the device to the concrete surface during the measures the propagation time of ultrasound for various concretes and conditions of the

surface was investigated in papers [4, 6]. Figure 3 shows the results of measuring the propagation time of ultrasound on the concrete surface when the pressure of the device changes. Measurements were made in 16 zones on the surface of four concrete samples, which were made of concrete of the same composition and using the same technology.

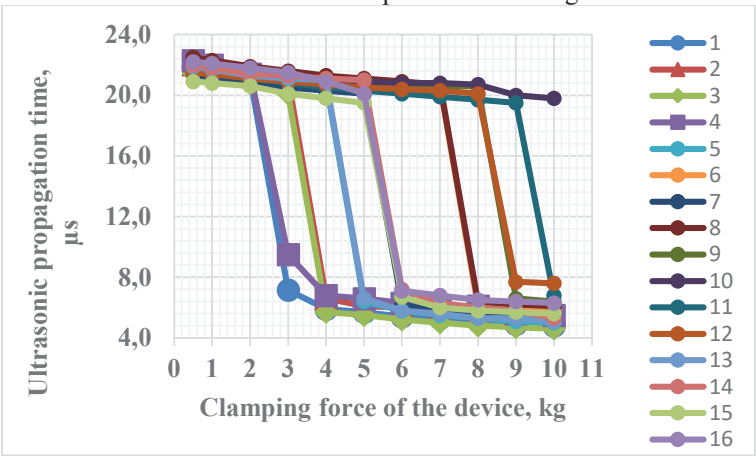

Fig. 3. Results of measuring the time of ultrasonic propagation on the surface of a concrete sample when changing the clamping force of the device

The results of the above studies show us that standardized procedures for measuring the speed (propagation time) of USV increases the measurement error, which reduces the accuracy of measurements and the adequacy of conclusions.

Based on the research carried out in laboratory conditions, a modernized ultrasonic method for periodic control of the material properties of structures is proposed.

The basis of the proposed improvement is the periodic measurement the ultrasound speed in the structure in prearranged zones. For this purpose, several places (benchmarks) are prepared for the installation of ultrasonic emitters-receivers, which allow spatial fixation of the USV, ensuring tight contact with the concrete of the structure.

The layout of such a benchmark is shown in Figure 4.

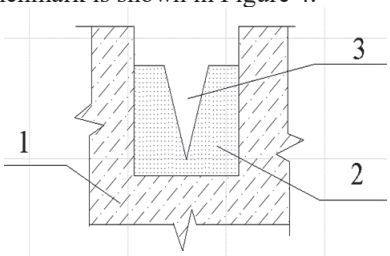

Fig. 4. Scheme of arrangement the benchmark: 1 - concrete; 2 - transition layer; 3 - seat for emitters of ultrasonic receivers

USV speed measurements are carried out in several directions to obtain the dependence “USV speed − angle of deviation from the vertex of the device” in each measurement zone.

The effectiveness of the proposed improvements was tested in the conditions of unfinished construction of a real 16-storey residential building (Fig. 5).

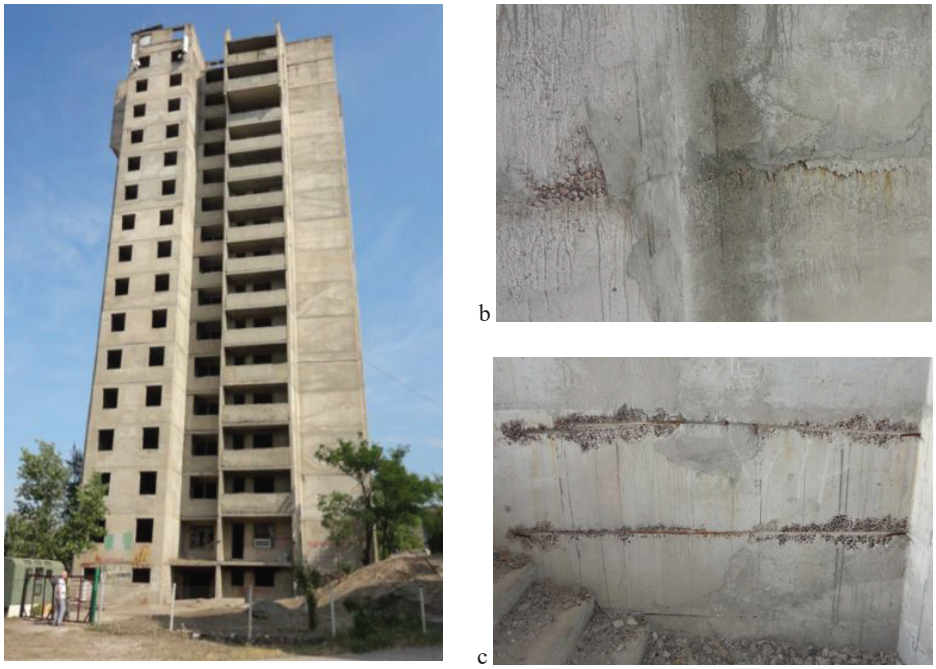

Fig.5. Unfinished: a − general appearance; b − consequences of vandals' actions; c − defects of concrete

Defects in the concreting (Fig. 5c) and concrete destruction during localized reinforcement removal (Fig. 5b) were detected while inspecting the facility.

The detected defects raised the question of the presence or absence of deformation processes in the structures of the entire building. The proposed modernization of the methodology for using ultrasonic devices made it possible to solve this problem with minimal costs.

A schematic diagram of the benchmarks placement is in Figure 6 and the placement of the ultrasonic transmitter-receiver for measurements is in Figure 7.

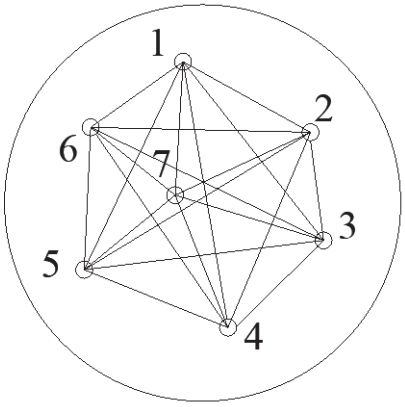

Fig. 6. Schematic diagram of placement of rappers: 1-7 numbers of rappers

Fig. 7. Placement of UZK emitters-receivers

This arrangement of reference measurement points (benchmarks) solves several tasks at once:

- measurements are performed in different directions;
- the obtained results reflect the effect of concrete stress on the measurement results;
- the presence of parallel sides makes it possible to carry out redundant measurements and quality control;
- the figure formed during the measurements forms the classic central system of geodetic trilateration, which allows you to calculate the angles between the measurement directions and carry out a joint balancing the lengths of the sides and angles of the triangles in the central system.

By balancing this trilateration system in a correlated or parametric way, we will obtain balanced values of the angles and distances of the central system of trilateration. The initial data for the calculations is the measured distances between the vertices of the central trilateration system (places of benchmarks in Fig. 6).

The preliminary calculations and the final balancing of the network were performed using the Credo_Dat software package.

Data pre-processing (preprocessing) is a mandatory preparatory step before balancing and searching for measurement errors. The main function of preprocessing is to check compliance with regulatory tolerances, generate average (weighted average) measurement values, reduce measurements, and convert measurement data and project parameters obtained from different sources to a single internal format.

Benchmark zones were arranged within stairwells. Measurements of the propagation time of ultrasound between reference points were carried out after measuring the distance between them.

The results of USV speed determinations on the 3rd, 7th and 11th floors are shown in Figures 8-10.

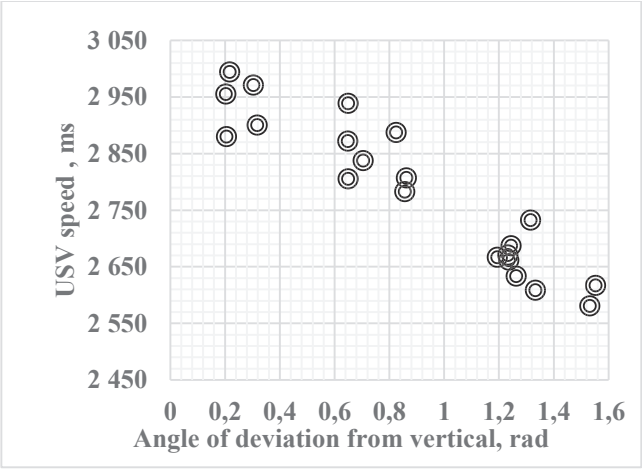

Fig. 8. The results of determinations the speed of ultrasound between the benchmarks on the 3rd floor

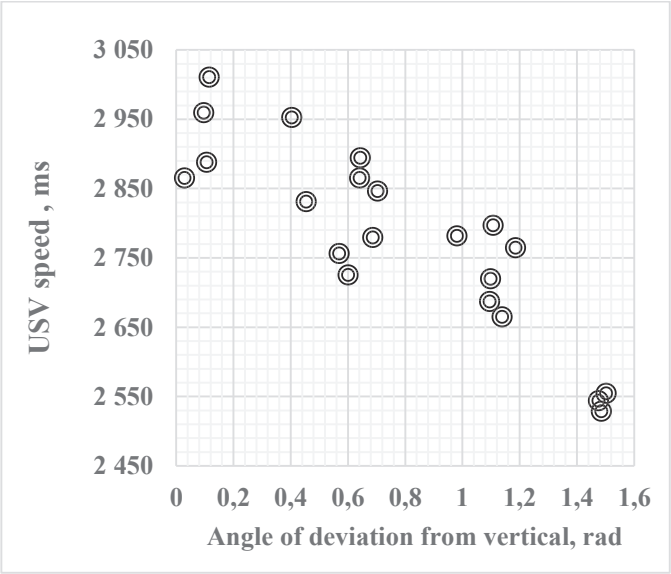

Fig. 9. The results of determinations of the speed of ultrasound between the benchmarks on the 7th floor

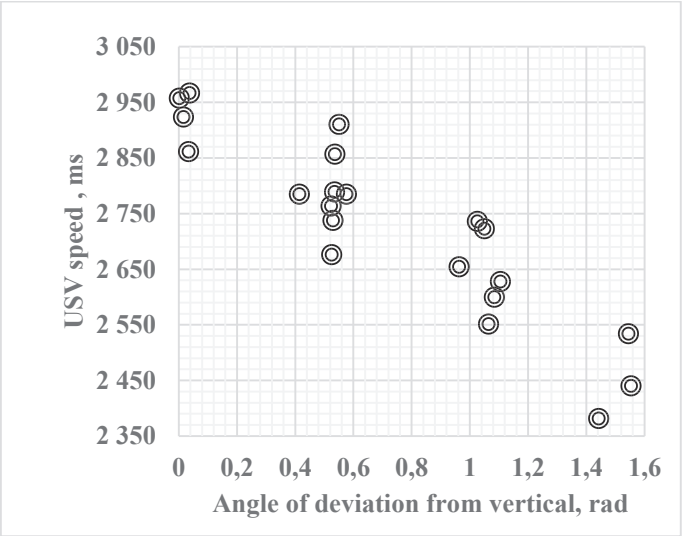

Fig. 10. Results of ultrasound speed determinations between benchmarks on the 11th floor

The above indicates the need for some refinement of the algorithm for carrying out work and data processing, namely in obtaining a wider range of deviation angles and in generalizing values with a slight deviation of the function argument.

To achieve the goals of the survey, determination was made in three cycles of observations. The time interval between measurement cycles was 70 days.

Table 1 presents the results of measurements and calculations for the reference zone of the seventh floor in three observation cycles.

Table 1. Results of measurements and calculations for the reference zone of the seventh floor.

Item no.	Direction	Length (reduced value), mm	Directional angle, rad	Time, ms			Speed, m/s		
				measurement no			measurement no		
				1	2	3	1	2	3
1	2	3	4	5	6	7	8	9	10
1	12	122.0 544	1.570796	45.6	46.4	45.9	2 677	2 629	2 658
2	13	213.0 484	1.066483	75.1	76.0	75.5	2 837	2 803	2 822
3	14	229.6 113	0.550971	83.9	84.9	85.0	2 737	2 704	2 700
4	15	198.0 949	0.018006	67.8	68.7	68.7	2 922	2 884	2 885
5	16	113.7 572	0.49882	39.7	40.1	40.9	2 865	2 835	2 780
6	17	116.9 438	0.550448	43.0	44.1	43.8	2 720	2 652	2 671
7	23	125.2 132	0.527778	44.6	45.7	45.0	2 807	2 738	2 783
8	24	202.7 117	0.015684	70.5	71.7	71.6	2 875	2 827	2 833
9	25	241.3 876	0.552154	83.4	84.2	83.7	2 894	2 867	2 882
10	26	209.1 996	1.062542	74.5	75.4	75.2	2 808	2 776	2 780
11	27	121.8 212	0.561632	44.7	45.1	45.7	2 725	2 700	2 667
12	34	118.6 949	0.573282	41.7	42.3	42.4	2 846	2 804	2 797
13	35	218.1 272	1.052322	78.9	80.0	79.4	2 765	2 725	2 748
14	36	248.5 214	1.563505	97.7	99.0	98.8	2 544	2 511	2 516
15	37	126.6 776	1.561444	47.0	47.4	48.0	2 695	2 672	2 638
16	45	125.6 777	1.486361	46.2	46.8	47.3	2 720	2 685	2 660
17	46	205.2 891	1.061853	73.8	74.3	74.2	2 782	2 762	2 765
18	47	112.6 769	0.551509	39.8	41.0	40.7	2 831	2 748	2 771
19	56	114.8 470	0.435237	39.9	41.1	40.3	2 878	2 792	2 852
20	57	119.7 924	0.543268	43.1	43.8	44.2	2 779	2 732	2 712
21	67	121.8 581	1.565682	44.2	44.6	44.6	2 757	2 732	2 734

The data presented in Table 1 show slight deviations from the average value, which indicates a stable state of the structures.

Such deviations can be explained by the error of the measuring device and the difference in the temperature and humidity during individual measurements. So far the state of the building's structures can be qualified as satisfactory, and the used methodology can be recommended for use during the determination of the state of the structures and periodic control.

3 Conclusions

The conducted research shows that:

1. The developed method of periodic control for the properties of concrete structures confirms the low complexity of the work and sufficient reliability of the obtained results.
2. It is necessary to carry out certain refinements of the algorithm of work and data processing.
3. It is possible to propose the following methodology for determining the technical condition of operated structures and periodic control.

References

1. DSTU b V. 2.7-220:2009, Building materials, Concretes, Determination of strength by mechanical methods of non-destructive testing. Introduced for the first time (with cancellation of GOST 22690-88); effective from 2010-09-01. Kyiv, Ministry of

Regional Development of Ukraine, 20 (2010). (National Standard of Ukraine). https://online.budstandart.com/ua/catalog/doc-page?id_doc=25945

2. DSTU b V. 2.7-226:2009, Building materials. Concretes. Ultrasonic method of determination of strength. Introduced for the first time (with cancellation of GOST 17624-87); effective from 2010-09-01. Kyiv, Ministry of Regional Development of Ukraine, 27 (2010). (National Standard of Ukraine). https://online.budstandart.com/ua/catalog/doc-page?id_doc=25948
3. V.V. Kolokhov, Yu.O. Kozhanov, D.M. Zezyukov, The influence of the voltage level on the propagation speed of ultrasonic vibrations in concrete structures. Bulletin of the Prydniprovska State Academy of Civil Engineering and Architecture **1 (249-250),** 49-57 (2019). https://doi.org/10.30838/J.BPSACEA.2312.260319.49.405
4. V.V. Kolokhov, O.V. Kolokhov, Change in the propagation time of ultrasonic vibrations in concrete due to changes in the conditions of measurement. Bulletin of the Prydniprovska State Academy of Civil Engineering and Architecture **2 (251-252),** 96-105 (2019). https://doi.org/10.30838/J.BPSACEA.2312.280519.95.411
5. V.V. Kolokhov, O.V. Kolokhov, Some aspects of measurement of propagation time of ultrasonic vibrations in concrete. Bulletin of the Prydniprovska State Academy of Civil Engineering and Architecture **3 (253-254),** 58-65 (2019). https://doi.org/10.30838/ J.BPSACEA.2312.040719.58.464
6. Kolokhov V.V., A.M. Sopilnyak, A.S. Smirnov, Measurement of the speed of ultrasound during the determination of the technical condition of the racks of overpasses of technological pipelines. Bulletin of the Prydniprovska State Academy of Civil Engineering **5 (257-258),** 49-56. (2019). https://doi.org/10.30838/ J.BPSACEA.2312.221019.50.522
7. Kolokhov V., Aplying ultrasound detection devices to examine properties of concrete structures. Materials Science Forum **1038,** 424-429 (2021). https://doi.org/10.4028/ www.scientific.net/MSF.1038.424
8. V. Kolokhov, L. Kushnerova, L. Moroz, T. Pavlenko, On providing an assessment monitoring system for especially essential structures: conf. paper. Materials Science Forum **1006 MSF**, 130-135 (2020).