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NON-DESTRUCTIVE INTEGRITY ASSESSMENT OF BORED PILES BY THE SEISMIC-ACOUSTIC METHOD UNDER FIELD CONDITIONS

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ABSTRACT

Introduction. The quality control of bored piles is an important issue in geotechnical construction, since hidden defects in the pile shaft may reduce the bearing capacity and reliability of pile foundations. Non-destructive testing methods make it possible to assess the integrity of piles underfield conditions without damaging their structural body. **Methods and Materials.** The article discusses the application of the seismic-acoustic method for assessing the integrity of bored reinforced concrete piles. Field testing was carried out using the SPECTR-4.3 seismic-acoustic device, which records the response of the pile to an external impact and allows the obtained signals to be interpreted in the form of reflectograms. The study considered bored piles with a diameter of 1000 mm and a design depth of 21.0 m. The method was used to determine the actual pile length and to identify possible defects, including discontinuities, shaft narrowing or widening, soilinclusions, and other concrete heterogeneities. **Results and Discussion.** The results of field testing showed that the measured lengths of the investigated piles ranged from 21.11 m to 21.92 m. The obtained reflectograms did not reveal significant defects, sharp changes in cross-section, ordiscontinuities in the pile shafts. This indicates that the actual condition of the tested piles corresponds to the design requirements and confirms the proper quality of pile construction. **Conclusions.** The research results have shown that the seismic-acoustic method is an effective and informative tool for rapid non-destructive integrity assessment of bored piles under field conditions. Its application increases the reliability of engineering quality control and can be recommended for the inspection of pile foundations at construction sites.

KEYWORDS: bored piles; non-destructive testing; seismic-acoustic method; pile integrity; fieldtesting; pile foundation; concreting defects.

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1 INTRODUCTION

Pile foundations are widely used in the construction of buildings and structures under complex engineering-geological conditions, particularly when the upper soil layers do not possess sufficient bearing capacity. Bored piles have become especially common, as they allow structural loads to be transferred to denser and more stable soil layers. However, the quality of such pileslargely depends on drilling technology, borehole bottom cleaning, installation of the reinforcementc age, concreting procedures, and compliance with construction quality control requirements[1]. One of the key issues in the construction of bored piles is the possible formation of hidden defects within the pile shaft. Such defects include discontinuities in concrete, narrowing or widening of theshaft, soil inclusions in the concrete mix, cavity formation, material heterogeneity, and insufficient pile length. These defects are practically impossible to detect visually, since most of the structure islocated within the soil mass. Therefore, non-destructive testing methods are used to assess the quality of piles. Pile integrity testing is defined as a non-destructive test in which the response of a pile to acertain type of indirect physical scanning is investigated. Integrity testing is most commonly used aspart of a pre-planned quality control programme developed for a specific construction site [2-3].

The main testing methods currently used may be identified as follows:

a) low-strain pile integrity testing;
b) cross-hole sonic logging;
c) thermal integrity profiling;
d) parallel seismic testing;
e) high-strain dynamic testing.

Most pile integrity tests used worldwide are based on measuring the acoustic properties of apile by applying an impact to it or by generating another type of acoustic vibration within it. Such amechanical impulse produces “impact” or “acoustic” waves, which propagate along the pile orthrough its body at a velocity determined by the material properties of the pile. Figure 1 presents typical types of pile shaft defects detected during pile integrity testing. [4-6]. The transmission of these waves through the pile is most conveniently described and analysed using stress wave propagation theory, which is based on the principles of one-dimensional wave mechanics in elastic rods. [7-15].

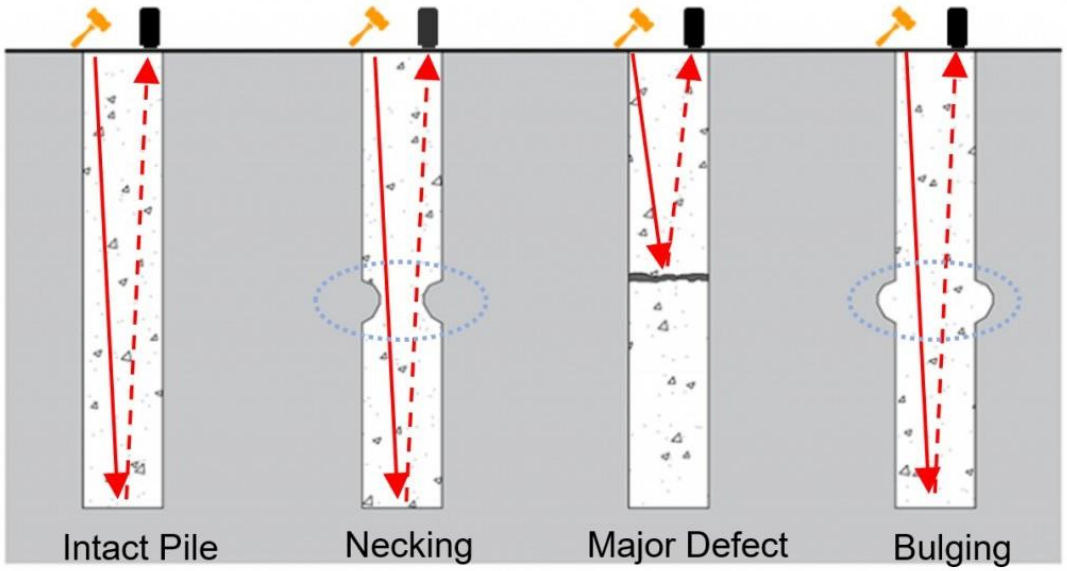


Fig. 1. Typical pile defects identified during pile integrity testing [4]

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2 METHODS AND MATERIALS

The research materials consisted of the results of field non-destructive testing of bored reinforced concrete piles carried out using the seismic-acoustic method. The object of the study was bored piles installed under construction site conditions and designed to transfer loads from abuilding or structure. Particular attention was paid to assessing the integrity of the pile shaft and identifying possible concreting defects, discontinuities, necking, soil inclusions, and other heterogeneities that may occur during pile construction. Seismic-acoustic testing was performed using the SPECTR-4.3 device, designed to record andanalyse wave signals generated in the pile body under impulse excitation. Figure 2 shows the general view of the device and its components. The equipment set included a measuring unit, a vibration sensor, an impact device, connecting cables, and software for processing the obtained signals. Before testing, the pile head was prepared: its surface was cleaned of dirt, weak concrete, and irregularities, since the quality of contact between the sensor and the concrete surface has a significant effect on the reliability of the results.

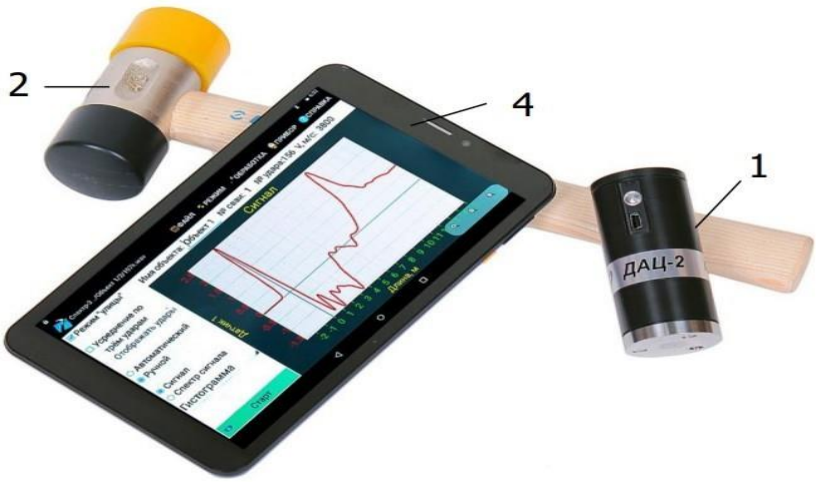


Fig. 2. General view of the SPECTR-4.3 device. 1 - DAC wireless digital vibration acceleration sensor; 2 - Hammer with damper (SPECTR-4.3); 4 - Tablet PC [1]

Seismic-acoustic flaw detection using the “SPECTR-4.31” pile diagnostic device is applied to assess pile integrity under field conditions, regardless of the pile type. The method is based on instrumental recording of the response of the tested pile to external impacts with specified impulse parameters. The signal is recorded by an accelerometer sensor connected to a special computer equipped with software for digitising and interpreting the obtained data (Figure 3). The processed results are presented as computer-generated graphical images, or reflectograms, which indicate thepile length, integrity, presence of damage, and its location.When the pile head is struck with a hammer, an acoustic longitudinal compression-tensionwave is generated, which propagates through the pile body at velocity c. The acoustic properties of concrete structures differ significantly from those of dispersed soil. Concrete piles have relatively low energy losses due to attenuation and re-radiation into the soil mass. Sound waves are reflected at the boundaries between different media, such as concrete-defect or concrete-soil interfaces. The time interval

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between the hammer impact and the reflected wave from the interface is recorded bythe sensor and is equal to the time t required for the wave to travel twice along the full pile length l, downward and upward.

$$T = \frac{2l}{c} \quad (1)$$

The pile length l is determined based on the time interval t of wave propagation. In this case, the wave propagation velocity is assumed to be unknown:

$$l = \frac{ct}{2} \quad (2)$$

According to the principles of elastic wave propagation, the velocity of an elastic wavedepends on the properties of the medium:

$$c = \frac{Ed}{p} \quad (3)$$

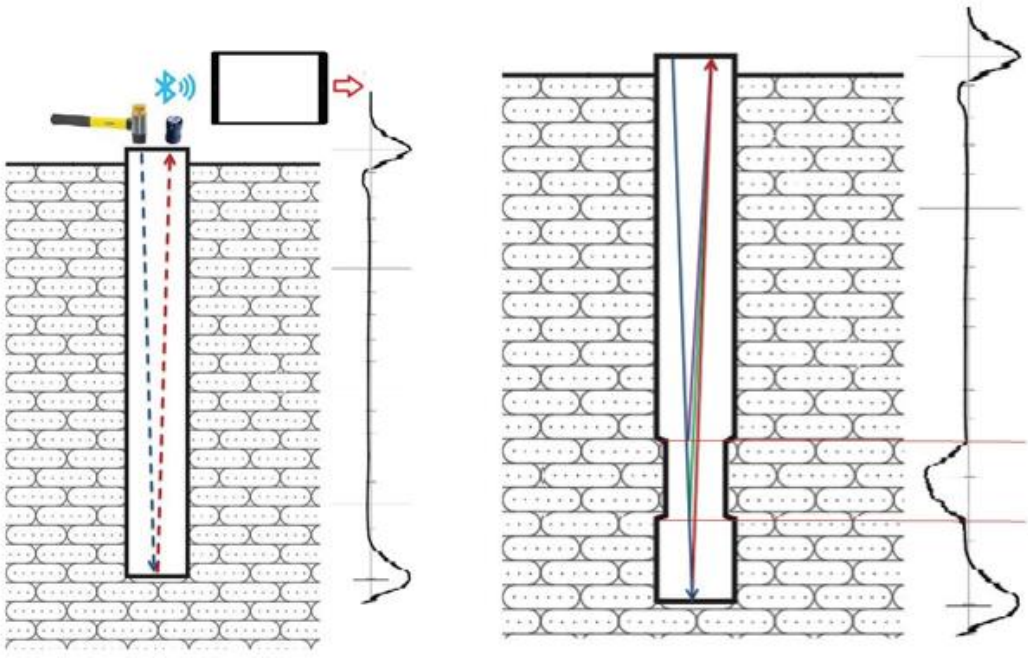
Defects are characterised by changes in the cross-sectional area of the pile shaft, as well as by variations in the concrete properties, including the dynamic modulus of elasticity E and density ρ (Figure 3). It is known that the velocity of elastic wave propagation is higher in stronger materials.

Although the method is relatively simple to perform under field conditions, it requires considerable time and professional expertise for subsequent data processing in order to avoid incorrect conclusions. To prevent distortions caused by different soil layers, it is necessary to study the design and working documentation, and to interpret the recorded signals with reference to the engineering-geological investigation data.

3 RESULTS AND DISCUSSION

Pile integrity testing of bored piles was carried out directly during the construction of the foundation for an industrial building. The purpose of the testing was to determine the pile length, within the limits of measurement accuracy, and to identify abrupt changes in the cross-sectional area of bored piles, such as necking or widening, exceeding 25% of the pile cross-section

A total of 12 bored piles with a diameter of 1000 mm and an embedment depth of 21.0 m were tested. The results of the pile integrity testing are presented in Figures 5-16.



a) b)

Fig. 3. (a) Principle of the seismic-acoustic wave method for pile integrity testing [1]; (b) diagram of sound wave propagation in a pile with a defect [2]

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A total of 12 bored piles with a diameter of 1000 mm and an embedment depth of 21.0 m were tested. The results of the pile integrity testing are presented in Figures 5-16.

Based on the results of the pile integrity testing, it was established that the measured pile lengths ranged from 21.11 m to 21.92 m. No defects were detected in the tested piles.

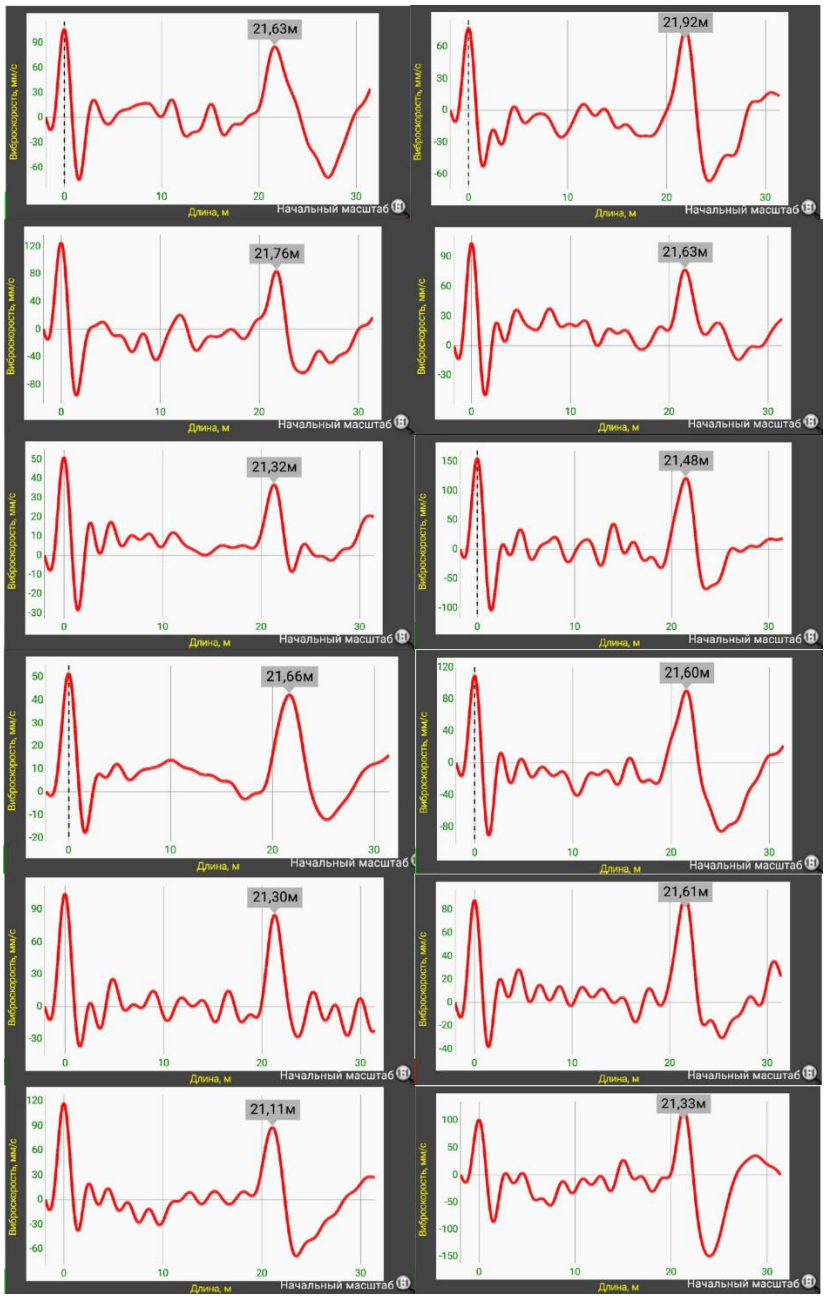


Fig. 3. Results of pile integrity testing for bored piles with a length of 21 m and diameter of 1000 m

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Table 1. Pile Integrity Testing Log

№	Pile №	Measured pile length, m
1	315	21.63
2	299	21.92
3	315	21.76
4	324	21.63
5	273	21.32
6	325	21.48
7	298	21.66
8	288	21.60
9	275	21.30
10	280	21.61
11	281	21.11
12	306	21.33

4 CONCLUSION

1. The conducted study confirmed the effectiveness of using the non-destructive seismic-acoustic method for assessing the integrity of bored piles under field conditions. This method makes it possible to promptly determine the actual pile length, identify possible discontinuities in the concrete shaft, abrupt changes in cross-section, zones of heterogeneity, and other hidden defects without disturbing the structural integrity of the pile foundation.

2. During the field investigation, bored reinforced concrete piles with a diameter of 1000 mm and a design embedment depth of 21.0 m were tested. Based on the processing of seismic-acoustic signals, it was established that the actual length of the tested piles ranged from 21.11 m to 21.92 m. The obtained reflectograms showed no significant defects, sharp necking, widening, or discontinuities in the pile shafts. This indicates that the actual condition of the piles complies with the design requirements and confirms the proper quality of pile construction works.

3. Seismic-acoustic testing has demonstrated its practical significance as a rapid and informative method for field diagnostics of pile foundations. Its application is particularly relevant for the mass inspection of bored piles, when it is necessary to assess the quality of completed works within a short period of time and confirm the absence of hidden defects in the pile body.

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CONFLICT OF INTEREST

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During the preparation of this manuscript, the authors used [tool name, version] solely for language editing and grammar checking. The authors reviewed and edited the output and take full responsibility for the scientific content, analyses, interpretations and conclusions of the article.

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AUTHORS CONTRIBUTION

Abdrakhmanov D.I. – writing an article; scientific editing of the text; identification of dependencies; conducting the experimental part of the study.
Dzhumadilova S.Zh – scientific guidance; research concept; development of methodology; scientific text editing; final conclusions.
Zhamek N.A. – preparation of samples; writing an article; processing of experimental data; accumulation of material.
Khomyakov V.A. – conducting a literary review; conducting the experimental part of the study.

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