NEW METHODS AND INSTRUMENTS IN MINING

CONTROL OF LENGTH OF CONCRETE PILES IN SOIL
BY THE ACOUSTIC PROBING METHOD

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The prototype of portable device is developed and approved for probing the concrete piles located in soil. The procedure for determining the pile length is proposed.

Pile, length, impact, probing, spectrum

In the construction practice, the operative estimate is required for the state of pile foundations in building reconstruction, as well as for the sizes of separate piles and their conformance to the design values. The actuality of this problem is confirmed by the recent appearance of the publications on theoretical development of the methods and measuring systems for nondestructive control of different elements of building structures [1–6]. The data on successful use of acoustic echolocation for estimating the technical state of bridge piers, reinforced concrete beams, and frames are available in [7, 8]. In such cases, the primary information source is the echo-signal recorded after excitation of the object under investigation by ultrasonic or impact pulse. The use of echolocation for probing the piles located in soil is complicated by strong attenuation of the acoustic pulse, which is connected with the energy dissipation at the pile – soil interface. This situation requires the development of special measuring system.

Having analyzed and generalized the experience of probing different objects, the authors of this paper created and approved in situ the experimental prototype of the device for determining the length of piles located in soil. This device ensures amplification of the initial impact pulse and the echo-signal considerably differing in the amplitude, as well as their recording on the measuring tape-recorder. The source information is processed by the method of spectral-resonance analysis based on excitation of vibrations in the tested object at the resonance eigenfrequencies as a result of single impact action [7]. These frequencies manifest themselves in the form of peaks in the spectrum of the recorded vibrations and are arranged with strict periodicity. The difference in frequencies of the neighboring peaks is associated with longitudinal size of the object. The spectral-resonance analysis expands the possibilities for echolocation in difficult cases when the reflected signal is weakly distinguishable.

The impact loading of the pile under test ensures high intensity and wide frequency range of the excitation pulse, decreases the recording time, and makes it possible to estimate attenuation; at the same time, the requirements to amplifying equipment increase. In particular, the impact is accompanied by high-frequency spurious components of high intensity, which overloads the input circuit of the amplifier. This phenomenon can be prevented by the band-pass filter with a fixed frequency range or by mechanical impact damping. Besides, due to considerable attenuation of the excitation pulse, the amplifier with the gain coefficient increasing in time is required for recording the reflected signals. The preliminary experiments showed that in the piles lying on the soil surface, up to ten reflections are recorded, whereas in the completely driven ones — no more than two reflections.


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Figure 1 presents the scheme of the measuring system which takes into account all the features of acoustic probing of the piles located in soil. It contains piezoelectric accelerometer 1, the acoustic pile probing device consisting of blocks 2–4, and tape recorder 7. The reliable and stable contact between the accelerometer and the pile was ensured by special fusible quick-hardening composition.

The probing is realized in the following way. A blow is delivered on the center of pile end surface 6 by hand hammer 5; it is directed along the pile axis for decreasing the amplitude of bending vibrations. Accelerometer 1 fastened immediately at the point of impact takes up the vibrations of the pile end and transforms them to the electric signal entering the input follower with band-pass filter 2 whose pass band is 50–2000 Hz. If the signal from output 2 exceeds a certain threshold level, we actuate block 3 forming the voltage pulse of the triangular shape, which enters the control input of block 4 and smoothly changes its gain coefficient from 0.5 to 40. This process lasts 30 ms; then, block 3 returns to the initial state. Its operating period corresponds to the arrival time of the reflected pulse. The amplified signal from block 4 is recorded on the tape recorder (model 7003 produced by Brüel & Kjær Company). Later on, the data are digitized under the laboratory conditions (AD converter produced by Data Translation Company, model 2821) and processed by the spectral-resonance method. From the moment of impact to the moment of maximum amplification, the signal spectrum is obtained by the Fourier transform. The part of pile protruding from soil should not exceed 25–30 cm; otherwise, it will become the source of weakly damped resonance vibrations entering the band of recorded frequencies, which impedes the analysis of echo-signal.

Figure 2a presents a typical oscillogram of acceleration on the end of the filling pile 0.4 m in diameter. This oscillogram is recorded in-situ after the impact. Its spectrum (Fig. 2b) contains low and high eigenfrequencies of longitudinal pile vibrations. The disposition of peaks of the observed resonances is stable within one series of measurements. The corresponding calculated spectrum of acceleration is shown in Fig. 3. Obviously, the peaks are similar in disposition of the frequency maximums. The distinction in the peak amplitudes is connected with the impact imperfection and dissipative properties of the pile and the soil; however, it is not essential for determination of length. The frequency-resonance method requires only availability of the data with respect to the frequencies. If the sonic speed $C$ is known (for concrete piles, it is 3200–4000 m/s), then the length of pile is calculated from the formula: