

ІНФОРМАЦІЙНІ РЕСУРСИ ТА СИСТЕМИ

УДК 620.179.1.001.5

Oleksij Lebid¹

Ph. D., Senior researcher, Acting Deputy Director for Science

Iurii Kaliukh²

D. S., Professor, Deputy Head of Department

Yaroslav Berchun¹

Postgraduate of Department of natural resources

Dmytro Chernyshev³

Ph. D., Associate professor, First vice-rector

¹Institute of Telecommunication and Global Information Space of NASU, Kyiv, Ukraine

²State Enterprise "State Research Institute of Building Constructions", Kyiv, Ukraine

³Kyiv National University of Construction and Architecture, Kyiv, Ukraine

IDENTIFICATION OF DEFECTS OF THE PILES WITH REFLECTED WAVES

Abstract. *Using current mathematical models of wave processes does not allow diagnosing defects in piles with sufficient accuracy. The necessity of creating of a pile generalized dynamic model which would allow to receive more reliable signals of wave processes in reinforced concrete piles has been substantiated. For numerical simulation of dynamic processes, a flat scheme for an axisymmetric pile based on the finite element method of "deep beam" within LIRA software complex was used. Sand was chosen as the soil around the pile due to the fact that sand and concrete characteristic impedance is very different, which provides a good echo from the pile toe (from the interface of the media). A comparative analysis of the results of mathematical modeling has made it possible to state that the most informative (in terms of differences in the comparison of graphs from one another), both for time signals and amplitude spectra, is the application of a horizontal impact on the lateral surface near the border with the pile base and the signal recording that comes to the speed sensors located in the vertical direction on the pile head near the border with the lateral surface. This option will be thoroughly tested numerically and experimentally in subsequent authors' studies.*

Key words: *identification, defects, pile, reflected waves, numerical simulation.*

Introduction

The determinants of possibility of construction of high-rise residential and public buildings on the allocated site are the soil composition and its bearing capacity. This influences the choice of the footing type. According to the world practice, three basic variants of footings are used in the high-rise buildings construction, such as: slab, pile and slab-pile [1]. Solutions for many high-rise buildings in Moscow have been implemented and are implemented on a slab basis with significant subsidence – up to 20 cm and more. But the ratio of height to the width of the smallest base on these objects does not exceed 4. If the value of this ratio is more than 6 in high-rise buildings due to increasing of settlements and tilt, it can cause serious problems [2]. The prevention of the above problems is facilitated by the use of pile and slab-pile footings, as well as technical means for supervision (monitoring) the house and its separate elements [3] for timely management decisions making. German experience suggests that before the 80s the high-rise buildings in Frankfurt am Main had been built on a slab footing, and after the 80s years – on a slab-pile one [2, 4].

In Ukraine, for high-rise buildings, which are characterized by large loads on a soil basis, in order to reduce settlement and tilts, the following variants of footings are recommended: pile, deep supports of high bearing capacity (such as "barrettes", etc.), slabs, including increased stiffness (boxed), combined slab-pile according to the standards [5]. The above facts show that the higher and the more complex the building is, the more appropriate is the use of footings based on piles. At the same time, as for the high-rise buildings, the standards [6] do not allow to use those types of piles in which it is impossible to control the quality of their arrangement and reinforcement throughout the depth. Let us consider the existing methods of technical condition of reinforced concrete structures and feasibility analysis of their use for the piles diagnostics.

Reinforced concrete piles, unlike other reinforced concrete structures, have several features. At first, access to grounded piles is limited to one free end and a lateral surface, the total area of which, as a rule, does not exceed 5–10% of the total area of the pile surface. Secondly, in the process of reinforced concrete piles placing in the soil, defects such as bugholes, weakening of neck intersection, breaks of the bearing, thickening of the bearing or cambers for drill piles; may appear in the soil not characteristic of other types of reinforced concrete structures; scratching, slant fractures and breaking piles with the displacement of their pieces into the ground – for the spud piles. Thirdly, solidifying of the concrete mixture of piles in its upright position leads to unevenness of the impact of its own weight of the pile along its length. As a result, the heterogeneity of the design is possible – the physical and mechanical properties of the concrete along the length of the pallets can vary significantly, which directly affects the stiffness of the building [7].

Main part

The methods for reinforced concrete piles technical condition assessment in terms of the above features are subject to certain limitations compared with standard diagnostic methods developed and applied for most types of reinforced concrete structures. Let's consider some of them:

Mechanical methods of non-destructive control of reinforced concrete structures are based on the connection between the strength of the concrete and the indirect

strength characteristics (the value of hammer rebound resiliency; the value of local failure effort of concrete during removal of anchor device from it; the value of the effort necessary for the local destruction of concrete during a break of a glued metal disk from it; the size of the impression on the concrete when the indenter is pushed into the concrete surface, etc.) according to the predefined grading dependencies. However, the above methods give an idea just of the technical condition of concrete areas of reinforced concrete structures which were tested. The quality of concrete mixture laying in the pile is also checked using radioisotope and ultrasonic methods (pulsed and echo method).

Radioisotope methods. There are three schemes for concrete mixture solidity monitoring in the well, based on the radioisotope method:

- The investigated medium (concrete) is located between the radiator (usually radioactive isotopes C_0^{60} and C_0^{137}) and the receiver (gas discharge and scintillation counters). At the same time the pile bearing axis in the diametrically opposite points bore two test wells are drilled. In one of them the radiator is put, and in the second – the receiver. In the course of concreting, the bearing shines in its fixed points along its height;
- Instead of two or three longitudinal bars of the armature frame the gas pipes are installed. One of the tubes down the emitter, in the second – the receiver;
- The radiator and receiver are in the same capsule – radio sounder. This method is based on the Compton effect.

The described methods have a number of shortcomings; in particular, there is no continuous control over the continuity of the concrete mixture, which is checked only in part of the cross section of the pile.

Ultrasonic pulse method. Ultrasonic pulse method has been widely used since the 70s of the last century in order to control the piles quality [7, 8]. This method is based on the relationship between the speed of ultrasonic vibrations spread in concrete and its strength. It is most often used for solving problems of determining the strength characteristics of non-metallic building materials and concrete materials test. Measurement of informative parameters is performed by the through sonic test method, when the converters are placed coaxially from the opposite sides of the controlled product, or by the surface sounding method – when the transducers are placed at a fixed distance (sounding base) on the surface of the product [8].

The basic document regulating the definition of the concrete strength on compression by the ultrasonic method is GOST 17624-87 [9]. The ultrasonic pulse method is standardized and widely used in other countries (DIN 1048 p.2, ISO / DIS 8045, EN 124398, BS 1881-201: 1986, etc.).

The main advantage of this method is that testing a large number of sites doesn't take much time. Its essential limitation is that it is used mainly to control the strength of *concrete structures with open access*. However, access to reinforced concrete piles immersed in the soil is minimal, that greatly limits the possibilities of this method in determining the strength of concrete in piles, in the conditions of their heterogeneity.

Echo method. According to the classical scheme of the method, an electrically acoustic transducer radiating placed on an accessible surface excites a compression wave in the object. Distributing through the product, it is reflected from defects, heterogeneities, boundaries of the construction. The receiving transducer, mounted on the same surface near the transmitter, receives reflection, converts it into electrical signals that enter the recording equipment. For the registration and analysis of wave processes in the control object in most of the serial defect detector an oscillographic method is used [10].

However, reinforced concrete as a material for control by acoustic methods has its own characteristics, in particular heterogeneity. Concrete-bonded fillers and steels create heterogeneity in the size up to several tens of millimeters, on which a short ultrasonic wave will disperse (the dispersion of the wave energy), and as a result – extinguish intensively. The experimental analyses of the frequency dependence of ultrasonic oscillations extinction coefficient on the concrete composition have demonstrated that the main energy of the probing signal should be concentrated in the frequency band below this range. At such frequencies, the wavelength of the signal is several centimeters. Such waves correspond to frequencies of 25–100 kHz.

There are devices for working with concrete that use frequencies of the above order. Their practical tests demonstrate that accurate results with their help can be obtained only for piles, the length of which does not exceed 6 m. It is practically impossible to increase the power of the probing pulse by increasing the amplitude of the electric impulse that is excited by the piezo-radiator. This amplitude limits the intensity of the alternating electric field, which can be sustained by a piezoceramics without breakdown.

Summing up the abovementioned, one can conclude that any of the standard methods of quality control of reinforced concrete constructions does not meet the requirements for conducting technical control of piles immersed in soil to the full extend. The only promising way out of the situation is a development of new diagnostic methods that would take into account all the specifics of the complexity of work with concrete piles in the soil. These are methods that use low-strain integrity testing: impact-echo, pile driving analysis, dynamic testing, parallel seismic test, impedance log test, etc. The most common modification of this method is the impact echo method (in the terminology [10]), known in the world under the name impact-echo. This method proved to be the most suitable for wide application in assessing the technical condition of reinforced concrete piles constructed in the soil.

Impact echo method is the improved ultrasonic pulse echo-method. Its main difference is that the pulse excitation is performed not with a piezo radiator, but with a special impact device. Typically, such a device is conventional hammers weighing from several hundred grams to several kilograms with replaceable caps [11]. The diagram of the impact echo-method is shown in Fig. 1.

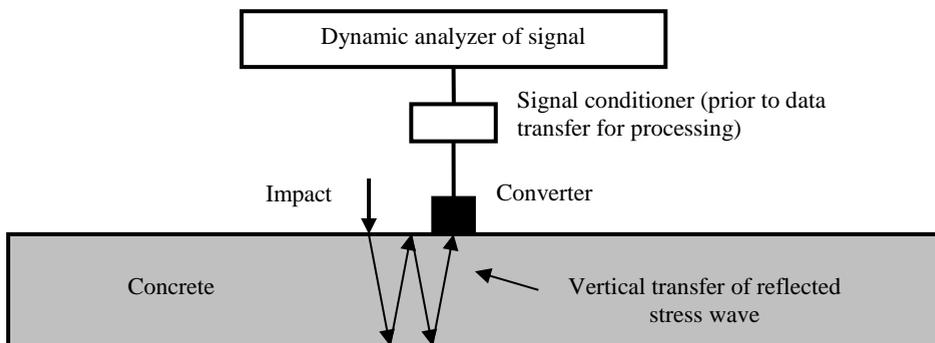


Fig. 1 – Impact echo method outline diagram

Works by Sansalone, M.J. and her co-authors [12] subsequently contributed in making up of regulatory documents by the American Society for Testing and Materials (ASTM) [13, 14]. Further research on this topic is reflected in the works of Liao [15]. They aimed to explore the possibility of different approaches to their excitation using the theoretical model of wave processes transfer in the piles: dynamic testing, parallel seismic test, impedance log test. All these approaches, like impact echo method, have been tested in practice. The use of impact echo method in order to determine the continuity of long concrete piles was theoretically and practically proved in Argentina under the supervision of Ambrosini D. [16]. As the theoretical model, Ambrosini used the same model of wave processes transfer as Liao, but summarized it by substantiating the possibility of using this model together with the apparatus of impact echo method for flaw detection of piles having a relation between length and diameter of about 40.

According to the State Construction Standards of Ukraine DNB B.2.2-24: 2009 [6], the diameter of the piles should be at least 620 mm while the length is up to 25 m and not less than 820 mm while the length is over 25 m. This means that the ratio between the length and diameter of piles for high buildings varies from 30 to 40. It was previously thought that the echo method can be useful only in the case when the relationship between the length and diameter of the pile does not exceed 20 [16], therefore the results obtained by Ambrosini are of great significance for the diagnostics of reinforced concrete piles of high buildings foundations. There are also devices in Ukraine that implement impact echo method, although they are not in full-scale production. This is TKS-1, developed by the State Enterprise "State Research Institute of Building Constructions"(SRIBC) and KSDK-3.3, developed by the Kyiv National University of Civil Engineering and Architecture (KNUCEA) [17]. The disadvantage of the TKS-1 device, as well as its Russian analog, is the lack of theoretically valid criteria for the identification and classification of defects in the surveyed reinforced concrete piles. Decision making as for the quantitative and qualitative characteristics of defects in a pile is a responsibility of the operator whose input information is only for the time and spectral characteristics of the signal received by the device. The essence of the spectral processing is to determine the fundamental frequency of oscillations, which corresponds to resonance along the entire length of the pile. If there are defects in concrete, additional frequencies are determined. They correspond to resonances along the length of the pile relative to these defects. The theoretical models used by researchers of piles diagnostics are represented in Table 1.

Insufficient efficiency of the piles integrity express test on the basis of time processing of the impact pulse due to the difficulty of obtaining the echo signal from its base is shown on the example of composite piles [20]. Fig. 2, a, Fig. 2, b shows the results of time and spectral processing of the composite piles signals using the TKS-1 device. The time signal (Fig. 2, a) allows to detect the reflection only from the piles junction (4.1 ms), whereas the frequency peaks of 120 Hz and 260 Hz which correspond to reflection from the base and from the junction were reliably recorded in the spectra of the signal (Fig. 2, b).

Table № 1 – Wave processes modeling in state-of-art and world technologies

Medium class	Using – where and by whom	Model fundamental equation	Numeral signals processing methods	Possibilities
Elastic medium	«Pile length indicator» Device by «LogiS» Company (Russia) and «Spektr 2.0» [18]	$\frac{\partial^2 u}{\partial x^2} = \frac{1}{\gamma^2} \frac{\partial^2 u}{\partial t^2}$	Time-domain	Piles length measurement, significant defects isolation
	Device TKS-1, SE «SRIBC» (Ukraine)	$\frac{\partial^2 u}{\partial x^2} = \frac{1}{\gamma^2} \frac{\partial^2 u}{\partial t^2}$	Time-domain, spectral, signal filtration	Essential reducing or increasing of pile cut, composed piles diagnostic
Maxwell Visco-elastic medium	System KSDK-3.3 (KNUCEA)	$\frac{\partial^2 u}{\partial x^2} = \frac{1}{c_0^2} \left(\frac{\partial^2 u}{\partial t^2} + \frac{1}{\beta} \frac{\partial u}{\partial t} \right)$	Time-domain	Automated sorting out of piles with significant defects
Kelvin-Voigt visco-elastic medium	Mary Sansalone (USA) [12], Shu-Tao Liao (Canada) [15], Daniel Ambrosini (Argentina), [16], Dong Soo Kim (South Korea) [19] and others.	$\rho \frac{\partial^2 u}{\partial t^2} = E \frac{\partial^2 u}{\partial x^2} + \epsilon \frac{\partial^3 u}{\partial x^2 \partial t}$	Time-domain, spectral	Reducing or increasing of pile cut more than 50% (in a laboratory environment – more than 30%)

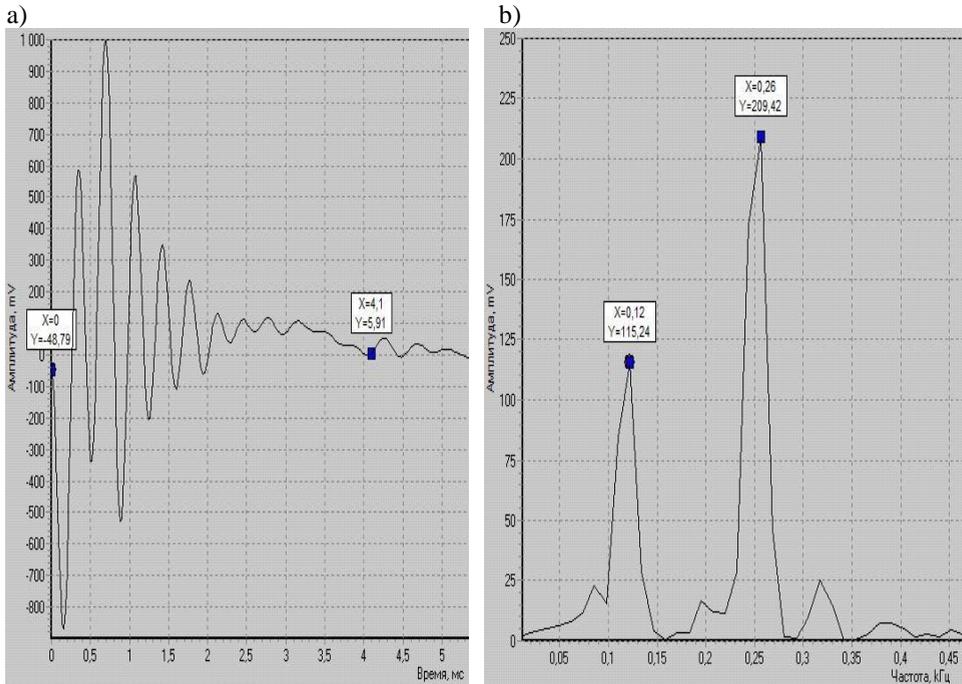


Fig. 2 – Results a) time domain and b) spectral processing of composite pile using TKS-1 Device, SE «SRIBC»

Summarizing the analysis of the works by principal local and foreign researchers in the field of evaluation of the technical condition of reinforced concrete piles for the foundations of high-rise buildings and structures, the following conclusions can be made:

1. Today, the technology of ground-based reinforced concrete piles control is based on the excitation of the low-frequency pulse wave with the subsequent recording of the time characteristics of its distortion by receivers installed on the surface of the pile. The results by Kim [19], Liao [15] Ambrosini [16] and other researchers have shown that the impact echo method can be used for diagnostic operation of reinforced concrete piles with a ratio of length and diameter of about 40, that is typical for piles of high-rise buildings foundations.

2. The theoretical models of wave processes (Table 1) used by Liao [15], Ambrosini [16] and Kim [19] are the same, and the results obtained by them are not fundamentally different. In order to raise the level of technology of control of ground-based reinforced concrete piles to a fundamentally new level, it is absolutely necessary to improve existing models.

3. In order to identify and classify defects in piles, a new theoretical basis must be developed [21–24] and corresponding well-founded criteria as well; otherwise the decision on the availability of these defects and their characteristics completely depends on the qualification of the operator – the "human factor". That is, when using the same equipment and test instrumentation on the same pile case, it is possible to obtain different, sometimes opposite, conclusions that will directly affect the reliability of the building that will be erected on this pile field.

Mathematical and numerical simulation

To simulate the processes taking place in the pile, we use a flat circuit for an axisymmetric pile. The flat model we build on the basis of finite elements of the "deep beam" type. We assign the number and size of the elements of the model. We select the dimension of the elements due to the following considerations: the elements of the model that correspond to the soil may be larger in size, since the accuracy of the calculation of the inner processes is not important; the elements of the model corresponding to the pile, on the contrary, are small enough to provide a rather high accuracy of calculations and an easy remodeling. The length of the piles will be equal to 12 m, the diameter will be 0.8 m. The piles consistency is equal to 2500 kg/m, elastic module is 3×10^6 t/m². Sand was chosen as the ground around the pile; it is typical for modern high-rise buildings in Kiev, being built on hydraulic fill. Such soil choice is also due to the fact that the sand and concrete characteristic impedance is very different, which ensures a good echo from the pile toe (from the interface of the media). The soil consistency is 1.66 t / m³, and the elastic modulus is 2.4×10^3 t/m². Based on these considerations, we select the size of the elements of the soil mass, place them in such a way that they together form the soil mass $3 \text{ m} \cdot 15 \text{ m}$ on both sides of the pile, as well as to the depths 3 m below the pile. We choose smaller dimensions of the pile elements $0.1 \text{ m} \cdot 0.1 \text{ m}$ in particular. The general view of reinforced concrete pile model in the soil is shown on Fig. 3. The elements of the pile are marked in blue; the elements of the soil are brown. Since the load in the program code "LIRA" [23, 24] is transmitted through the elements nodes the breakdown of the soil mass elements directly contacting pile elements was performed to fulfill the above condition (Fig. 3). Elements of the soil mass are depicted in yellow.

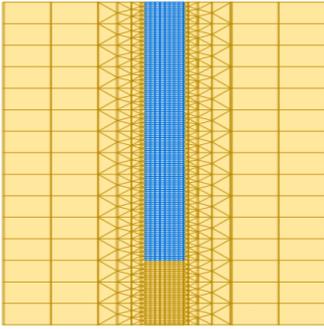


Fig. 3 – General view of pile free from defects

The soil mass elements located right below the pile are also divided into elements that are equal $0.1m \cdot 0.1m$. This will allow changing the "length" of the pile, thereby expanding the capabilities of the calculation scheme. To simulate defects in a pile (at a depth of 7 meters) the graphic models have been developed (Fig. 4), where the pile elements are marked in blue, the soil elements are brown.

An initial displacement of the concrete particles of the pile free end surface as a result of the impact was calculated (Fig. 5, a, b). The impact parameters are designed for a hammer with a total weight of 700 g with a spherical fluoroplastic tip with diameter of 40 mm. Broken line with an unspecified step was built on 11 points, selected unevenly on a sinusoidal arc with a half-period of 1.2 ms. Step by time – $2 \cdot 10^{-5}$ s; Signal length is 0.1 s.

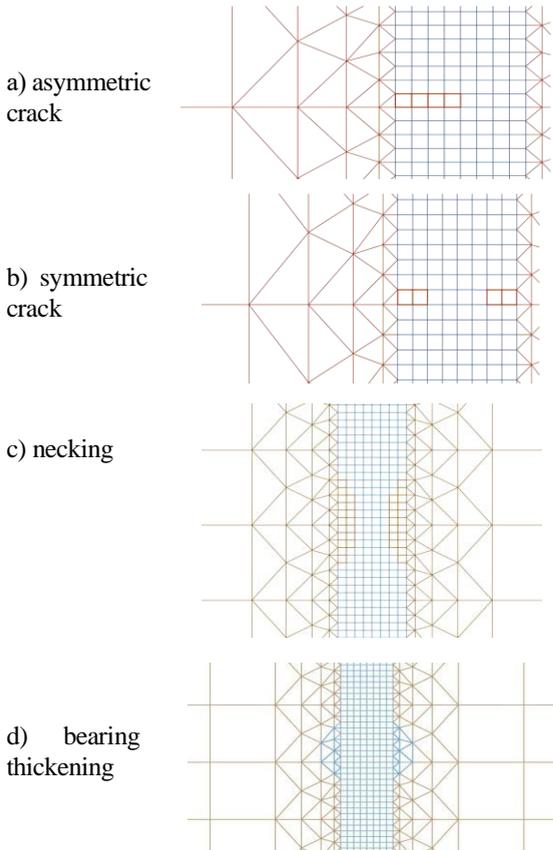


Fig. 4 – Graphic models of the pile defects simulation (on 7 m depth)

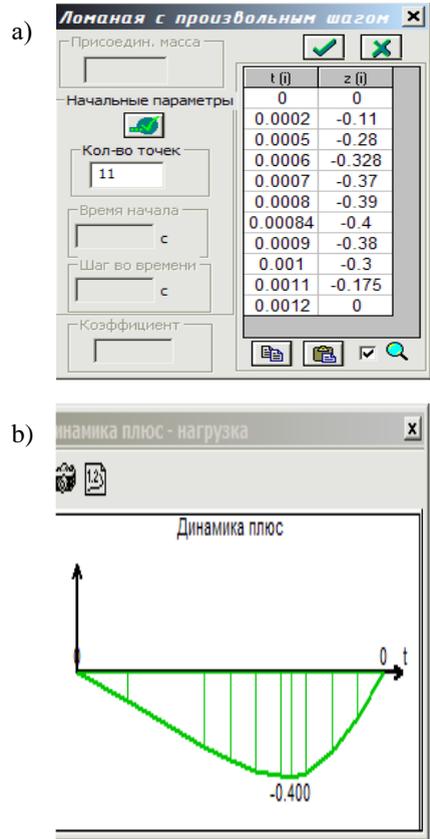


Fig. 5 – Initial displacement of concrete particles on the surface of pile free end caused by an impact

Research results

A comparative analysis of the results possible to establish that the most informative for both time signals and amplitude spectra is the application of a horizontal impact on the lateral surface near the base with the base and the registration of the signal coming to the speed sensors located vertically to the head of the pile near the boundary with a lateral surface (Fig. 6).

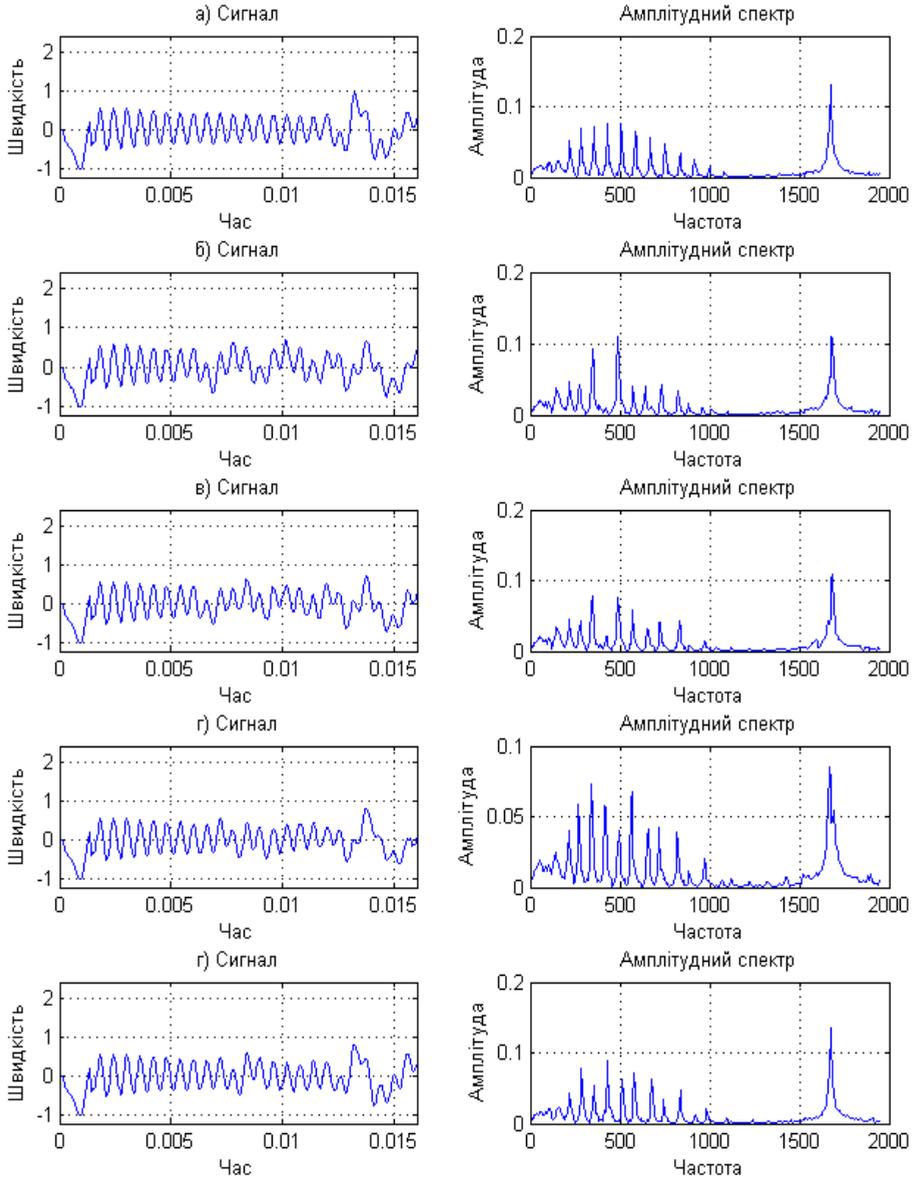


Fig. 6 – Modeled signals coming to speed sensors arranged in a vertical direction on the pile head near the border with the lateral surface, during a horizontal impact on the lateral surface near the border with the pile base: a) with no defects; b) with crack; c) with bug hole; d) with neck; e) with bearing thickness

For further confirmation or simplification of these findings, further experiments of the piles on soil with different defects will be conducted. of mathematical modeling has made it. Table 2 integrates variants simulated multiply. The following pile graphic models were calculated within all the variants: a) with no defects; b) with asymmetric crack; c) with neck; d) with bearing thickness. The location of the receiver (speed sensor) is marked in grey in Tab. 2, bold text is the place of the impact on the pile is highlighted in bold text.

Table 2 – Variants of numerical simulations

№	Simulations using LIRA 9.6 application software
1	Simulated signals coming at speed sensors located vertically in the middle of the pile base, as well as their amplitude spectra during a vertical impact on the pile head.
2	Simulated signals coming at speed sensors arranged in a vertical direction in the middle of the pile head, during a horizontal impact on the side surface near the border with the pile base.
3	Simulated signals coming at speed sensors, arranged horizontally in the middle of the pile head, during a horizontal impact on the side surface near the border with the pile base.
4	Simulated signals coming at speed sensors arranged in a vertical direction on the pile head of near the border with a lateral surface, during a horizontal impact on the side surface near the border with the pile base.
5	Simulated signals coming at speed sensors arranged horizontally on the pile head near the border with the lateral surface, during a horizontal impact on the side surface near the border with the pile base.

Conclusions

1. The theoretical models of wave processes used by Sansalone, M.J. [12], Liao [15], Ambrosini [16] and Kim [19] are identical, and their results do not fundamentally differ in any way. In order to improve the control technology of reinforced concrete piles built in the ground, it is extremely necessary to generalize and refine the existing models.

2. For the simulation of the processes taking place in the pile, a flat scheme for the axis of the symmetric pile is used based on finite elements of the "dee beam" within LIRA software complex. The length of the piles in mathematical modeling was taken at 12 m, the diameter – 0.8 m. The pile consistency is 2500 kg/m, the elastic module – 3×10^6 t/m². Sand was selected as the ground around the pile, which is typical for modern multistory buildings in Kiev. This choice of soil is also due to the fact that the characteristic impedance of sand and concrete is very different, which ensures a good echo from the pile toe (from the interface of the media).

3. A comparative analysis of the results of mathematical modeling has made it possible to state that the most informative (in terms of differences in the comparison of graphs from one another), both for time signals and amplitude spectra, is the application of a horizontal impact on the lateral surface near the border with the pile base and the signal recording that comes to the speed sensors located in the vertical direction on the pile head near the border with the lateral surface (Fig. 6). This option will be thoroughly tested numerically and experimentally in subsequent authors' studies.

Acknowledges

The authors of the article express sincere gratitude to Andriy Vusatyuk – PhD student supervised by Dr. of Eng., prof. Iurii Kalyukh. He, with the help of his supervisor, contributed a lot in mathematical and numerical simulation of the piles stress-strain state by finite elements and differences methods, as well as in collaborative pilot experimental studies on the basis of the SE SRIBC.

REFERENCES

1. Design and installation of bases, foundations and underground parts of multi-functional high-rise buildings and complexes: MDS (Methodical Documents in Construction) 50-1.2007. – [in effect since 8 Sept 2006]. – M.: NIIOSP named after N.M. Gersevanov, 2007.
2. Nikolaev S. V. About the first experience as for design and construction of high-rise buildings. / Nikolaev S. V. – POISK. From design to key №2, 2007.
3. Ulitskiy V.M. High-rise construction in St.-Petersburg / Ulitskiy V.M., Shashkin A.G., Shashkin K.G. // Cities reconstruction and geotechnic construction, № 9, 2005.
4. Van Impe V.F. Deep footings: tendencies and development perspectives / Van Impe V. F. Lecture on International Seminar in St.-Petersburg 17–19 June 2004.
5. Construction objects safety and reliability system. Scientific and technical support of construction objects: State Construction Standards DBN V.1.2-5:2007. – [in effect since 01.01.2008] – K.: Minregionbud of Ukraine, 2007.
6. Buildings and structures. Design of high-rise residential and public buildings: State Construction Standards DBN V.2.2-24:2009. – [in effect since 2009-09-01]. – K.: Minregionbud of Ukraine, 2009.
7. Yermoshkin P.M. Arrangement of bored piles / Yermoshkin P.M. – M.: Stroizdat, 1982. – 160 p.
8. Hlukhovskiy V.P. Assessment of resistibility of masonwork by pulse methods for determining structures resource: Ph.D. thesis in Engineering Science: 05.23.01 / Hlukhovskiy V.P. – K., 2007. – 193 p.
9. Concretes. Ultrasonic method for resistibility determination: GOST 17624–87. – [in effect since 1988-01-01] – M.: The Ministry of Construction Materials Producing Industry USSR, 1986.
10. Yaras V.I. The automated system of express-diagnostics of concrete pillars and piles in soil: Ph.D. thesis in Engineering Science: 05.13.07 / Yaras V. I. – K., 2006. – 193 p.
11. Hlukhovskiy V.P. Results of studies on reinforced concrete piles diagnostics during the construction and reconstruction of buildings and structures. / Hlukhovskiy V.P., Marenkov N.H., Khylyko S.V. // Geotechnics World, № 4, 2008. – 34 p.
12. Sansalone, M. J.; Streett, W. B. 1997. Impact-Echo. Nondestructive evaluation of concrete and masonry. – Bullbrier Press, Ithaca, 336 pp.
13. ASTM Standards C 1383-98. Impact-Echo Method (Test Method for Measuring the P-Wave Speed and the Thickness of Concrete Plates Using the Impact-Echo Method).
14. ASTM: D5882-00. Standard test method for low strain integrity testing of piles. ASTM International.
15. Chih-Peng Yu and Shu-Tao Liao. Theoretical basis and numerical simulation of impedance log test for evaluating the integrity of columns and piles // Can. Geotech. J. 43, pp. 1238–1248 (2006).
16. Ambrosini D., Ezeberry J. Long piles integrity trough impact echo technique. Mecanica Computacional Vol. XXIV, Buenos Aires, Argentina, 2005. pp. 651–669.
17. Device description «Pile length measurement». Available at: <http://www.logsys.ru/device.htm>
18. Piles diagnostics device description SPEKTR-2.0. Available at: <http://www.interpribor.ru>

19. Kim D.S., Kim H.W., Kim W.C. Parametric study on the impact-echo method using mock-up shafts // NDT&E International 35 (2002), pp. 595–608.
20. Hlukhovskiy V.P. Control of long composite structures based on the echo method and spectral analysis of signals / Hlukovskiy V.P., Marenkov N.G., Vusatyuk A.E. // Construction, materials and components science, machine building, Collection of studies. Issue 47, – Dnipro, PGASA, 2008. – 762 p.
21. Kaliukh, I., Senatorov, V., Khavkin, O., Kaliukh, T., Khavkin, K. (2013) Experimental and analytic researches on technical state, design and operation of reinforced concrete anti-landslide structures for seismic dangerous regions of Ukraine. In: Proceedings of the Fib Symposium. 22–24 Apr 2013, Tel-Aviv, Israel, pp. 625–628.
22. Farenjuk G., Kaliukh I., Farenjuk E., Kaliukh T., Berchun Y., Berchun V. (2018) Experimental and Theoretical Diagnostics of Defects in Ferroconcrete Piles Based on Reflection of Longitudinal and Transverse Waves. In: Hordijk D., Luković M. (eds) High Tech Concrete: Where Technology and Engineering Meet. – pp. 1307–1317, Springer, Cham.
23. Trofymchuk O., Kaliukh I., Silchenko K., Polevetskiy V., Berchun V., Kalyukh T. (2015) Use accelerogram of real earthquakes in the evaluation of the stress-strain state of landslide slopes in seismically active regions of Ukraine. In: Lollino G. et al. (eds) Engineering Geology for Society and Territory – vol. 2, pp. 1343–1346, Springer, Cham.
24. Kaliukh I., Senatorov V., Marienkov N., Trofymchuk O., Silchenko K., Kalyukh T. (2015) Arrangement of deep foundation pit in restricted conditions of city build-up in landslide territory with considering of seismic loads of 8 points. In: Proceedings XVI ECSMGE, 13–17 Sept 2015, Edinburgh, Great Britain, pp. 535–540.

Text of the article was accepted by Editorial Team 02.02.2018

Лебідь О.Г., Калюх Ю.І., Берчун Я.О., Чернишев Д.О.

ІДЕНТИФІКАЦІЯ ДЕФЕКТІВ ПАЛІ ВІДОБРАЖЕНИМИ ХВИЛЯМИ

Анотація. Використання існуючих на сьогоднішній день математичних моделей хвильових процесів не дозволяє діагностувати дефекти в палях з достатньою точністю. Обґрунтована необхідність створення узагальненої динамічної моделі палі, що дозволяла б отримувати більш правдоподібні сигналограми хвильових процесів у залізобетонних палях. Для чисельного моделювання динамічних процесів використано пласку схему для вісесиметричної палі на основі методу скінченних елементів типу «балка-стінка» в програмному комплексі ЛПРА. У якості ґрунту навколо палі було обрано пісок у зв'язку з тим, що характеристичний імпеданс піску та бетону дуже відрізняються, що забезпечує якісне відлуння від підшви палі (від межі розділу середовищ). Порівняльний аналіз результатів математичного моделювання дозволив встановити, що найбільш інформативним як для часових сигналів, так і амплітудних спектрів є нанесення горизонтального удару по бічній поверхні біля межі з основою та реєстрація сигналу, що надходить до датчиків швидкості, розташованих у вертикальному напрямку на оголовку палі біля межі з бічною поверхнею. Цей варіант буде ретельно перевірений чисельно та експериментально в подальших дослідженнях авторів.

Ключові слова: ідентифікація, дефекти, палі, відображені хвилі, чисельне моделювання.

УДК 620.179.1.001.5

Лебідь О.Г., Калюх Ю.І., Берчун Я.О., Чернишев Д.О. **Ідентифікація дефектів палі відображеними хвилями** // Екологічна безпека та природокористування. – 2018. – Вип. 1 (25). – С. 64–76.

Для діагностування дефектів в палях з достатньою точністю обґрунтована необхідність створення узагальненої динамічної моделі палі. Для чисельного моделювання динамічних процесів використано пласку схему для вісесиметричної палі на основі методу скінченних елементів типу «балка-стінка» в програмному

комплексі ЛІРА. Порівняльний аналіз результатів математичного моделювання дозволив встановити, що найбільш інформативним як для часових сигналів, так і амплітудних спектрів є нанесення горизонтального удару по бічній поверхні біля межі з основою та реєстрація сигналу, що надходить до датчиків швидкості, розташованих у вертикальному напрямку на оголовку палі біля межі з бічною поверхнею.

УДК 620.179.1.001.5

Lebid O., Kaliukh I., Berchun Y., Chernyshev D. **Identification of defects of the piles with reflected waves** // Environmental safety and natural resources. – 2018. – Issue 1 (25). – P. 64–76.

The necessity of creating of a pile generalized dynamic model which would allow to receive more reliable signals of wave processes in reinforced concrete piles has been substantiated. For numerical simulation of dynamic processes, a flat scheme for an axisymmetric pile based on the finite element method of "deep beam" within LIRA software complex was used. A comparative analysis of the results of mathematical modeling has made it possible to state that the most informative (in terms of differences in the comparison of graphs from one another), both for time signals and amplitude spectra, is the application of a horizontal impact on the lateral surface near the border with the pile base and the signal recording that comes to the speed sensors located in the vertical direction on the pile head near the border with the lateral surface.

Автори (науковий ступінь, вчене звання, посада):

Лебідь Олексій Григорович

кандидат технічних наук, старший науковий співробітник, заступник директора з наукової роботи

Інститут телекомунікацій і глобального інформаційного простору НАНУ

Адреса робоча: 03186 Україна, м. Київ, Чоколівський бульвар, 13

тел.: +380963363773

e-mail: o.g.lebid@gmail.com

ORCID:0000-0002-4003-8068

Калюх Юрій Іванович

доктор технічних наук, професор, заступник завідувача відділу

ДП «Науково-дослідний інститут будівельних конструкцій»

Адреса робоча: 03037 Україна, вул. Преображенська, 5/2

тел.: +38(050) 415 35 91

e-mail: kalyukh2002@gmail.com

ORCID: 0000-0001-7240-4934

Берчун Ярослав Олександрович

аспірант відділу природних ресурсів

Інститут телекомунікацій і глобального інформаційного простору НАН України

Адреса робоча: 03186 Україна, м. Київ, Чоколівський бульвар, 13

тел.: +380 50 179 09 03

e-mail: berchun93@gmail.com

ORCID: 0000-0002-9373-2870

Чернишев Денис Олегович

кандидат технічних наук, доцент, перший проректор

Київський національний університет будівництва та архітектури

Адреса робоча: 03037 Україна, м. Київ, проспект Повітрофлотський, 31

тел.: (044) 241-54-91, 241-55-58

e-mail: taqm@ukr.net

ORCID: 0000-0002-1946-9242