INTEGRATING OF GEORADAR ANS SEISMIC STUDIES OF THE TAILINGS DAM

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ABSTRACT

Identification of water-saturated zones in the tailings dams is an actual scientific and practical task in terms of providing, first of all, their mechanical strength and filtration stability. The prevention of accidents in tailings is complicated by the circumstance that the processes of increased filtration, appearing and developing in the dam body, are not fixed on the initial stages by visual and traditional methods. Insufficiency, from the point of view of data completeness, of networks of piezometric boreholes on tailings dams does not allow solving the tasks of necessary information hydrological support. At the same time, the use of active-sounding geophysical study methods allows obtaining sufficiently detailed information about the peculiarities of the internal structure of the tailings dam and the degree of water saturation of the composing soils. A reasoned choice of geophysical methods, as well as their combination, allows increasing the level and reliability of obtained data at subsurface studies. The paper presents the results of in-situ experiments on the study of the tailings dam of the mining enterprise by different in nature wave GPR (georadar) and seismic methods. A comparative analysis of the conducted studies has allowed clarifying the internal structure and assessing the dam's condition, paying special attention to the identification of local zones of increased water saturation and filtration. Based on the calculated correlation coefficient of electromagnetic and seismic wave velocity values, it was revealed that synchronization of geophysical surveys allows significantly increasing the reliability of in-situ determinations, as well as obtaining more reliable data. The results of the studies are the basis for predicting the most vulnerable places (zones) of a bulk ground hydraulic facility, as well as the localization of water-saturated areas in the body of the ground structures with greater reliability and performance.

Keywords: *dam, an accumulator of liquid industrial waste, GPR and seismic surveys*

INTRODUCTION

Currently, the main trends of geophysics in the study of technogenically disturbed, including partially water-saturated, rocks and soils is to increase the information content and reliability of the data obtained [1-4]. A large number of applied geophysical methods indicate the absence of a single standard geophysical method, capable of providing prompt and high-quality obtaining the required information about the mining-geological environment, due to the complexity and ambiguity of the data obtained. At the same time, the joint use of different in-nature wave methods: electromagnetic (GPR) and seismic profiling allows receiving more reliable operative information about the internal structure and degree of water saturation of technogenically disturbed rocks and soils [1, 5, 6]. Therefore, the choice and integration of these geophysical methods can improve the performance and reliability of the data obtained in solving various problems [7], [8], [9].

In mining operations, a large number of industrial facilities are potentially hazardous and are therefore classified as hazardous and technically complex facilities that require regular inspections and monitoring. One of such industrial facilities is the tailing dumps with systems of embankment structures, a breach of which stability and functionality can lead to an abnormal (or emergency) situation in the technological mining chain.

The world practice of mining nature management has typical examples of accidents at the tailing dumps, which led to significant financial and socio-economic consequences [7], [10]. A comprehensive examination and monitoring of the internal structure and condition of the tailings with the use of operational geophysical methods create an information and technical basis for minimizing the risks of man-made accidents. The purpose of the work is to substantiate methodological approaches to the complex georadar and seismic survey of the tailings dam.

METHODS

To assess the state of water saturation and the internal structure of the technogenically disturbed rocks of the tailings dam, two cycles of integrated observations were carried out using seismic and GPR profiling methods [11], [12], [13]. The following indicators were taken for further analysis: for the seismic method - the ratio of longitudinal velocity to transverse velocity Vs/Vp; for the GPR method - electromagnetic wave velocity V.

Figure 1 shows the main results of the performed integrated research as a radarogram of the electromagnetic wave velocity V (a) and a seismic tomogram of the ratio of longitudinal to transverse velocity Vs/Vp (b). The Figure visually notes the similarity in the colour palettes reflecting the internal structural features and water saturation of the surveyed soil section. For quantitative comparison of seismic and georadar values, plots of the variability of the accepted controlled parameters of the obtained results along the profiling traces in separate sections at two pickets (Fig. 2, 3) were built.

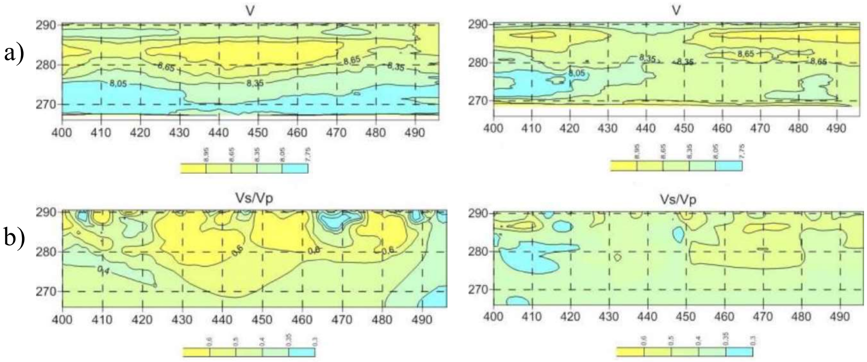

Fig. 1. *Results of integrated studies of soils with georadar (a) and seismic (b) profiling methods (left- 1st study cycle, right-2nd study cycle)*

EXAMPLES

Interpretation of the results of the first cycle of integrated seismic and GPR measurements (Fig. 1, left) suggests the following: In the central part, both the radarogram and the seismogram, the distribution of data reflecting the presence of dense soils of natural moisture has a fairly good visual convergence.

At the same time, in some areas, the colour palettes of the radarogram and seismogram reflect a visual discrepancy in the nature of the distributions of the values of the adopted indicators: V and Vs/Vp. On the radarogram we can clearly stand out the near-surface zone up to 2 m thick on two intervals of the profile (400-430 m and 470-480 m), in which the wetted soils prevail. At the same time on the seismogram the near-surface zone of moist soils is localized by small areas up to 5 m, and only at the end of the profile, at the interval of 470 m, a direct coincidence with the georadar profiling data is observed. In turn, according to seismic profiling data, water-saturated grounds are identified at the very end of the profile, in the interval 485-498 m, distributing over the whole depth of the seismogram, and according to GPR data, water-saturated grounds are identified throughout the profile, from a depth of 15 m and more (absolute marks 270-275 m).

These discrepancies can be explained, first of all, by the fact that seismic and georadar profiling were not performed simultaneously, but with a time difference of several days [14, 15]. During this period, the influence of natural (abundant precipitation such as rain) and technogenic (discharge of industrial water from an operating enterprise) factors, which also cannot be excluded, could have had an effect.

Interpretation of the analysed results of the 2nd cycle (Fig. 1, right), with synchronous seismic and GPR measurements, suggests the following. On the radarogram, the near-surface zone (to a depth of 1-1.5 m) of the profile up to 289 m, exposed to surface sediment penetration, is characterized by initial low-velocity V = 8.1-8.22 cm/nc, with its further sharp increase to V = 8.36-8.71 cm/nc at 8-10 m depth from surface (marks 282.5-280 m). Most likely, this is caused by density growth and decrease of ground humidity.

In the interval of heights 280-270 m there is a zone of sharp fall of velocity values to the values $V = 7.35\text{-}7.71$ cm/nc. Similar changes of Vs/Vp index are noted on the seismogram at the same marks, the values of which are 0.30-0.35, which allows us to conclude that soils here are subjected to considerable water saturation.

To compare the values of seismic and georadar results, we plotted the correlation between the values of the monitored parameters in the same sections at two pickets (Fig. 2, 3), for the first and second cycles of measurements, respectively.

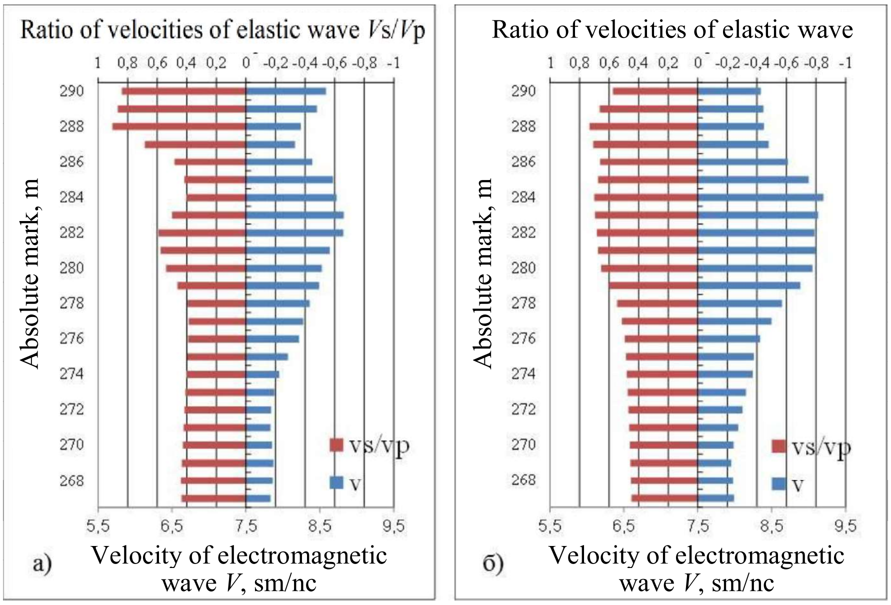

Fig. 2. *Comparison of seismic and georadar results of the 1st measurement cycle:*

a) PK4+10m, b) PK4+60 m

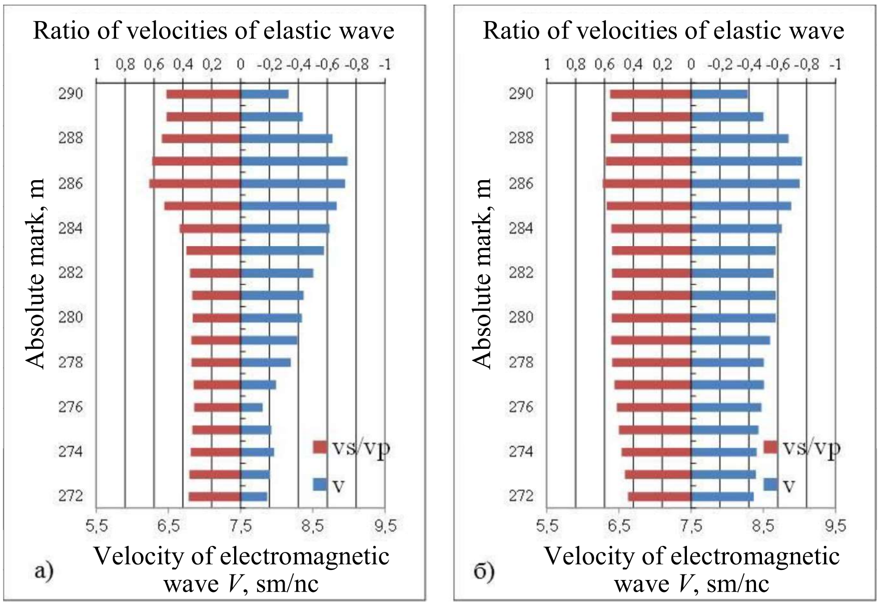

Fig. 3. *Comparison of seismic and georadar results of the 2nd measurement cycle:*

a) PK4+10m, b) PK4+76 m

Comparison of georadar and seismic profiling data, both on the first cycle and on the second, as well as in the aggregate on two cycles of measurements, showed the presence of confident correlation (convergence) of the obtained results. At the same time, GPR and seismic data of the second cycle of measurements have a closer correlation (Fig. 3), which is caused by the synchronization of measurements by two methods, in spatial-temporal coordination. In general, the correlation ratio calculated for the two measurement cycles has a range of values from 0.17 to 0.83 (except for individual values), with a predominant number of values from 0.4 to 0.6 or more (Fig. 4).

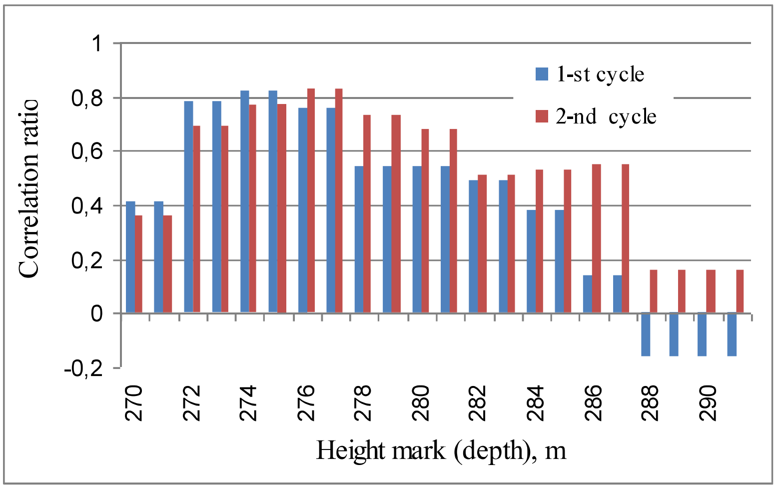

***Fig.4.** Correlation ratio of studied indices of georadar and seismic profiling*

CONCLUSIONS

To study the internal structure and state of technogenically disturbed soils of the tailings dam we carried out their research with a combination of GPR and seismic profiling, in two cycles: with a difference of several days and synchronously. Results of executed integrated surveys have allowed getting more reliable information about internal heterogeneity of technogenically disturbed soils due to unevenness of their water saturation. Zonal filtration heterogeneity of soils was revealed and their structure was clarified in the investigated area.

A comparative analysis of the values of the adopted indicators was performed: for the seismic method - the ratio of longitudinal velocity to transverse velocity Vs/Vp; for georadar method - electromagnetic wave velocity V. Good convergence of analysed indices for both cycles was revealed. At that, on the basis of the calculated correlation ratio of the analysed values, it was discovered that the synchronization of GPR and seismic surveys allow significantly increasing the reliability of in-situ studies, as well as to obtain more reliable data. The obtained results and new knowledge serve as an information-technical basis for integrating of georadar and seismic profiling of technogenically disturbed soils and substantiation of methodical approaches to comparative analysis of their results.

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