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RESULTS OF THE DAM STATE MONITORING AND SUBSTANTIATION OF CAUSES OF THE TAILINGS POND AREA DEFORMATION

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Abstract. The paper is aimed at the analysis of the results of geological engineering surveys of an active tailings pond to identify the dangerous dam areas and to define the reasons of deformation process progress within the dam to develop measures concerning geomechanical stability of the structure.

The paper involves both practices and monitoring results of an active tailings pond where concentration plant slurry is accumulated. The research subject is a dam of tailings pond Kryvi Luky belonging to Ordzhonikidze Mining and Processing Plant PJSC.

The international experience of accidents within the dams of tailings ponds was analyzed as well as all possible causes of the emergencies. It was proved that potentially dangerous processes and occurrences take place inside the mass. The necessity to monitor geomechanical stability of the hydraulic structure was substantiated.

The monitoring took several stages, which made it possible to trace through dynamics of the processes. Primary well drilling helped identify areas of the tailings pond dam where deformation processes take place; namely, zones of homogeneous pile clays; a zone of technogenic laminar filtering; and a zone of heterogeneous structure of the dam. Four years after, new inspection wells were drilled within the areas. Treatment of cores showed significant enlargement of sandy rock lenses differing in plastic consistency, which influences deformation processes in the dam. To identify the reasons of the geomechanically heterogeneous unstable zone, mining, hydrogeological, and engineering-geological conditions of the structure use were studied. It was defined that the problem dam area is located along a ravine; historically, land plot under the structure experienced flooding for many years; and geological framework of mass being the tailings pond basis was not prepared for the hydraulic structure building. To improve efficiency of further monitoring, it was proposed to set monumental benchmarks within the dam areas right in the zone where the layer of sandy rocks differing in plastic consistency becomes thicker.

The obtained results can be used for the development of measures to prevent emergency situations at tailings storage facilities, as well as to improve the efficiency of monitoring hydraulic structures.

Keywords: hydraulic structure, technical condition monitoring, geomechanical stability, deformations, tailings pond.

1. Introduction

Mineral mining and processing is followed by the accumulation of significant amount of dry and wet industrial waste. Dry waste of mining industry (i.e. overburden rocks and off-grade rock mass fragments at preparation plants) is stored within the mine dams. In turn, fine and dusty waste resulting from treatment process is delivered to tailings ponds by means of hydraulic transport [1].

Such hydraulic structures as tailings ponds experience significant loading by natural factors, namely water pressure; temperature variations; precipitation; and erosion. Stability of the facilities depends upon their ability to withstand such loads without failure or deformation, which would factor into serious accidents. Analysis of geomechanical stability of a hydraulic structure is critically important to provide its safe and reliable operation. Identification of the deviations from normal behaviour is the key aspect of stability analysis of such facilities.

Objects of this importance class are subject to relevant monitoring and control level involving both verification of correspondence with ratings/design parameters (monitoring of compliance with inwash technology-based standards; impounding; filtration mode; threshold pressure etc.) and constant monitoring of engineering status as well as serviceability of the set of hydraulic facilities being a part of the tailings pond.

Since 2011, Ukraine has been developing a new local monitoring concept concerning compliance by subsoil users with special requirements for mineral use, and implementation of scientific and technical support of the subsoil use. In other words, obtaining a special permit for subsurface use includes a clause on the obligation to perform monitoring and scientific support for fulfilment of special requirements.

Monitoring and scientific support of the subsoil use by environmental management facilities is a new procedure of government control over activities in the field of subsurface use. It is aimed at the improved efficiency and rationality of geological exploration and mining; substantiation of safe operation conditions etc.

The topicality and necessity to implement activities as for control of hydraulic structure state are stipulated not so much by regulatory documents as the need for timely identification of problem dam areas, and elaboration of measures to preserve their integrity. Unfortunately, numerous tailings pond accidents in many countries are known. They varied in their scope – from local emergencies up to catastrophes with human losses. Professor David John Williams in his paper [2] analyzed large-scale events happened in the first half of 20th century in South America, North America, Africa, and Australia. He studied not only causes of negative conditions of tailings pond use but also described further impact on updating the legislative documents of the mentioned countries.

In the context of the research, Associate Professor Leonid Rudakov performed capacious review of accidents within the dams of tailings ponds over the last thirty years. In his paper [3], the author listed countries where the accidents happened; mining enterprises and tailings ponds involved; reasons of the accidents; human losses; state losses; and environmental consequences. The analysis helped him draw a conclusion that ‘for the period, the majority of accidents happened in 34 world countries. The largest number of them was recorded in the USA (22.4%), China (10.4%), Brazil (7.5%), Chile (6.7%), the Philippines (6.0%), Canada (5.2%), the Great Britain (4.5%), and other countries’. Moreover, accident causes were listed relying upon the global experience: subsidence as a result of operations; erosion and suffosion; underground water impact; structural integrity disturbance; filtration processes; disturbance of the basis; seismic activity manifestations; rated capacity overflow; and dam stability disturbance. Consequently, the researcher developed a diagram as for percentage distribution of the causes, and the following conclusion was made ‘that instability of a dam slope (37%); overflow of the rated tailings pond capacity (12%); seismic activity manifestations (11%) etc. are the basic accident causes’.

Search for publications by such a key combination as ‘tailings dam accident’ in the largest eLibrary of special-purpose resources ScienceDirect made it possible to find more than 1900 scientific papers emphasizing worldwide interest in this problem. In addition, the Central Office of the INTERNATIONAL COMMISSION ON LARGE DAMS (ICOLD) performs extensive statistical work as for global registering, controlling, and monitoring of dams and dams. It is mentioned on the Office site [4] that their database includes more than sixty-two thousand facilities; the list is updating constantly. The problem of accident occurrence is global. World Information Service on Energy site [5] contains information as for the current methods to analyze tailings ponds as well as security measures concerning their use. In addition, discussions and research presentations in the field are also on the site. According to the data by the International Commission on Large dams, United States Society on Dams, Australian National Committee on Large Dams, and Canadian Dam Association, the major accidents in mining since 1960 have been recorded chronologically; moreover, a separate list of accidents within the tailings ponds of uranium mines is also available.

In view of considerable negative experience, the world practices pay much attention to mining waste management; safe handling of technogenic objects; and monitoring for timely response. The problem is common to Ukraine too [6]. In 1983, one of the largest environmental disasters happened in Soviet Ukraine, i.e. failure of Stebnyk tailings pond dam contaminated the Dniester River and even the Black Sea. Eventually, five million cubic meters of highly mineralized brine got to the Upper Dniester River basin [7]. In 2001, certain share of toxic dust waste spread to dozens of square kilometers due to a tailings pond damage at Mykolayiv alumina plant [8]. In 2008, accident at Kalush potassium plant resulted in waste getting into the Dniester River. In 2023, accident happened within central tailings pond (ArcelorMittal Kryvyi Rih) [9]. Due to the partially ruined dam, several suburban areas were flooded by industrial water in Myroliubivka.

Consequently, the paper purpose is to analyze the results of a series of engineering and geological surveys of an active tailings pond to determine the dangerous dam areas and identify the reasons of deformation process progress within the dam to develop measures concerning geomechanical stability of the structure.

2. Methods

Stage one involved a set of field observations (both visual and instrumental) as for the structure state; composition of the dam rocks; and base of the structure. For this purpose, following engineering and geological surveys were performed along the tailings pond dam Kryvi Luky in 2017:

1. Drilling of thirty wells (their initial diameter was 127 mm; their depth was 9.8–11.5 m; and the total boring volume was 323 r.m.).
2. Soil sampling (both disturbed and undisturbed structure). The samples of disturbed and undisturbed structure were taken using point sampling technique with their further packing in the sealed containers.
3. Laboratory-based determination of physicomechanical soil characteristics; chemical composition of ground water; formulation of soil-water extract etc.
4. Cameral treatment of the materials of the field and laboratory studies. Sections were developed with the description of lithological structure of rocks.

Relying upon the analysis, dam areas with non-homogeneous structure were identified as well as the areas for further monitoring.

Stage two (the year of 2021) involved the repeated engineering and geological surveys within the mentioned areas. Five wells were drilled (their initial diameter was

127 mm; their depth was 10.6–10.9 m) with soil sampling for further determination of physicomechanical properties of the soil.

Stage three involved analysis of mining, hydrogeological, and engineering-geological conditions to build and operate the structure, which made it possible to identify reasons of deformation process progress in the dam.

3. Results

There are 465 tailings ponds in Ukraine [8]. Their majority is in the east of the country and in Dnipropetrovsk Region. For the comparative analysis, tailings ponds with similar parameters were selected (five tailings ponds are in Nikopol manganese basin, Dnipropetrovsk Region). Table 1 demonstrates their generalized basic characteristics [10].

The current demands for design of hydraulic structures involve the detailed study of the land plot for construction as well as the adjacent territory; geology and hydrogeology which helps develop measures as for engineering environmental protection against negative impact by technogenic facility, and in turn a structure protection against impact by external factors. In the last century, no technological processes were available in our country as for preparation of both basis and shielding while building almost each tailings pond. In addition, lack of project documents raises a question concerning identification of the basic parameters of a structure building. Hence, we have such tailings ponds built mainly in the form of dams or enclosing walls (see Table 1). Sometimes, the mined-out areas of open pits were used for the purpose. Actually, all mining-and-processing integrated works operate for a long time; in such a way, rated capacity of the tailings ponds is almost exhausted. Visual condition of the dams indicates existence of potholes under them, opening of seams, and reed invasion. A state of water-intake and water discharge structures, slopes, berms, and dam edges need measures to be strengthened/renovated. Consequently, the current trend as for monitoring under scientific and engineering support makes it possible to analyze the structure state and develop timely measures for provision of maximum safe conditions of its use.

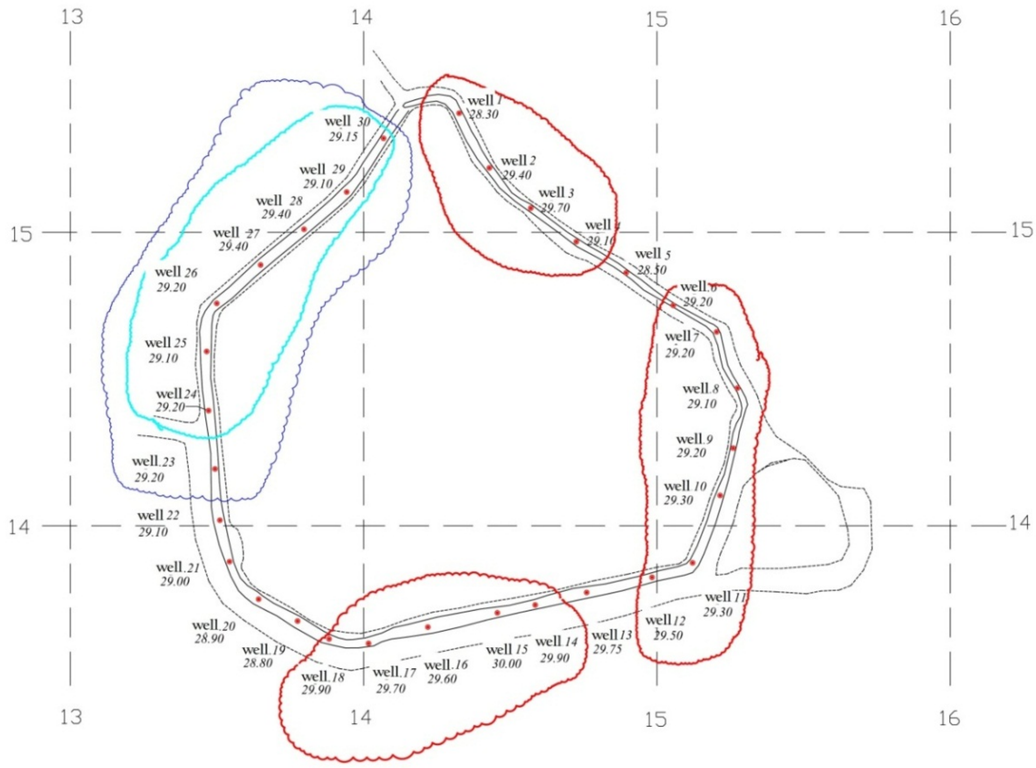
The total monitoring of technogenic objects includes complex of field observations (both visual and instrumental) controlled strictly by the national and industrial standards at different levels.

Dams of Kryvi Luky tailings pond (Ordzhonikidze Mining and Processing Plant PJSC) was selected for such monitoring. Initial studies were aimed at the analysis of geomechanical stability of the objects through geological engineering surveys with determination of geological and lithological composition of the ground cover; engineering and geological as well as hydrogeological conditions; physicomechanical soil characteristics etc.

Preparation step involved geological engineering surveys to actualize the topographic basis and form benchmark basis for following network of control points (Fig. 1).

Table 1 – Tailings ponds of Nikopol manganese basin, Dnipropetrovsk Region

Name	Location (settlement, district)	Mode of operation	Environmental safety category	Characteristic (volume, area, surface, underground) Sanitary protection zone area (SPZ)	Waste characteristic (name, group, class of danger)
Marhanets Mining and Processing Plant PJSC					
Tailings pond in Morozov ravine	14 km northeast of Marhanets	Active	B	Volume: sector 1 – the total volume is 42.4 million cubic meters, and usable volume is 41.4 million cubic meters; sector 2 – the total volume is 29.0 million cubic meters, and usable volume is 28.1 million cubic meters. Area is 230 ha, and 466.7 ha taking into consideration SPZ. Open; deepened in the ground.	Sludge and ore processing tails; group 13; class of danger 4
Tailings pond in Baburin ravine	1.3 km northeast of Marhanets	Active	B	Volume: the total volume is 16.0 million cubic meters and useful volume is 14.8 million cubic meters. The tank is pumpable. Area is 147 ha, and 225 ha taking into consideration SPZ.	Sludge and ore processing tails; group 13; class of danger 4
Tailings pond in Berehove ravine	1.8 km northeast of Marhanets	Active	B	Volume: the total volume of sector 1 is 4.720 million cubic meters (where useful volume is 4.52 million cubic meters; and water volume is 0.2 million cubic meters). The total volume of sector 2 is 5.230 million cubic meters (where useful volume is million cubic meters; and water volume is 0.2 million cubic meters). Area of sector 1 is 34 ha/71.7 ha; area of sector 2 is 34.8 ha/103.4 ha (taking into consideration SPZ). Open; deepened in the ground	Sludge and ore processing tails; group 13; class of danger 4
Tailings pond in Marievka open pit	0.9 km south of Marhanets	Closed	B	Volume is 0.36 million tons. Area is 142 ha, and 410.7 ha taking into consideration SPZ. Open; deepened in the ground	Sludge and ore processing tails; group 13; class of danger 4
Ordzhonikidze Mining and Processing Plant PJSC.					
Tailings pond in natural boundary Kryvi Luky	Southwest suburb of Pokrov	Active	B	Volume is 93.996 million tons. Area is 410 ha, and 953.6 ha taking into consideration SPZ. Open; surface	Sludges of ore treatment; group 13; class of danger 4



red boundaries are the zones of pile clays; blue boundary is a technogenic laminar filtering zone; and dark blue boundary is a zone of non-homogeneous structure of the dam basis

Figure 1 – Arrangement of wells of the geological engineering surveys in 2017

Relying upon the results of drilling and laboratory-based soil analysis, five engineering and geological elements were identified within the studied rock mass in terms of nomenclature characteristics and physicomechanical properties. The data were summarized in relevant tables of normative and design characteristics of physicomechanical characteristics of soils.

Geologically, the tailings pond is based upon the non-homogeneous mass of pile heavy clay loam with interlayers and lens of light clay and rare sand inclusions with complex internal structure of dams. In the neighborhood of wells 1–4, and 14–18, a layer of relatively homogeneous pile clays was defined in the basement of a tailings pond. Predominantly, the clay loam was heavy and silty with interlayers and inclusions of light clay. In the context of water extract composition, the soil was very injurious in terms of a sulfate activity degree. Moreover, the soil is of high corrosiveness as for lead coating and aluminium one.

During the period of the first engineering and geological surveys (i.e. during 2017), no ground water was available within the studied territory down to the explored depth being 9.8–11.5 m. However, in the neighborhood of wells 24–30, technogenic laminar filtering occurred at 2.1–8.2-m depth. The filtering did not have a constant level; nevertheless, certain watered areas were available (see Fig. 1). Water mass filtration took place through formation of light clay loam and sandy clay. Mass of heavy clay loam and light clay served as an aquifer (Fig. 2). A light sandy clay layer was of rather non-homogeneous structure. Near well 30, sandy loam lens was identified at 2-m depth. Sandy fraction had characteristic predominance within the lens.

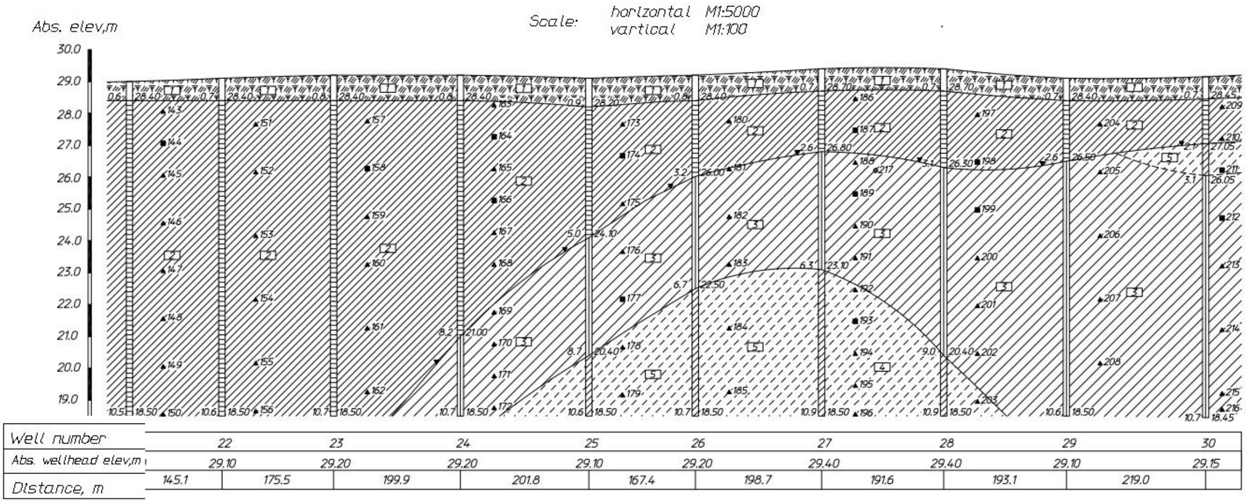


Figure 2 – Engineering and geological section (scheme) (the year of 2017)

Analysis of the tailings pond rock composition made it possible to understand that in the neighborhood of wells 23–30, lens-shaped layer of sandy-loam is spread in the basis of the mass; the layer underlies a light loam stratum. Potentially, such a dam structure is dangerous since it creates conditions for the development of suffosion processes resulting from a filtration crossflow of water mass from the Western section of the tailings pond to its Eastern section. Hence, a non-homogeneous structure zone of the dam basis and technogenic filtration zone where separate watered areas arise are of similar periphery. At the expense of such a non-homogeneous structure of a dam basis, rock consolidation was not achieved.

The analysis of rock composition within the dam basis helped identified that any impermeable membrane was not applied while building.

The availability of the non-homogeneous mass of pile heavy clay loam with interlayers and light clay lens provoked formation of laminar filtering zone of technogenic water. Consequently, a decision was made to continue monitoring of the hydraulic structure state. Therefore, the second set of engineering and geological surveys was performed in 2021 within the area differing in dangerous conditions. Five inspection wells were drilled to control a zone of non-homogeneous dam structure as well as a technogenic filtration zone (Fig. 3).

Well core processing analysis helped construct stratigraphic columns; in addition, geological section of the dam area was upgraded (Fig. 4).

In the neighborhood of 1-3 wells (corresponding to wells 26-28 drilled in 2017 respectively), significant increase in thickness of plastic consistency sandy loam layer was identified.

In the neighborhood of wells 4 and 5 (corresponding to wells 29 and 30 drilled in 2017 respectively), considerable growth in plastic consistency sandy loam lens was seen. The fact is demonstrated by the engineering and geological section (see I-I line).

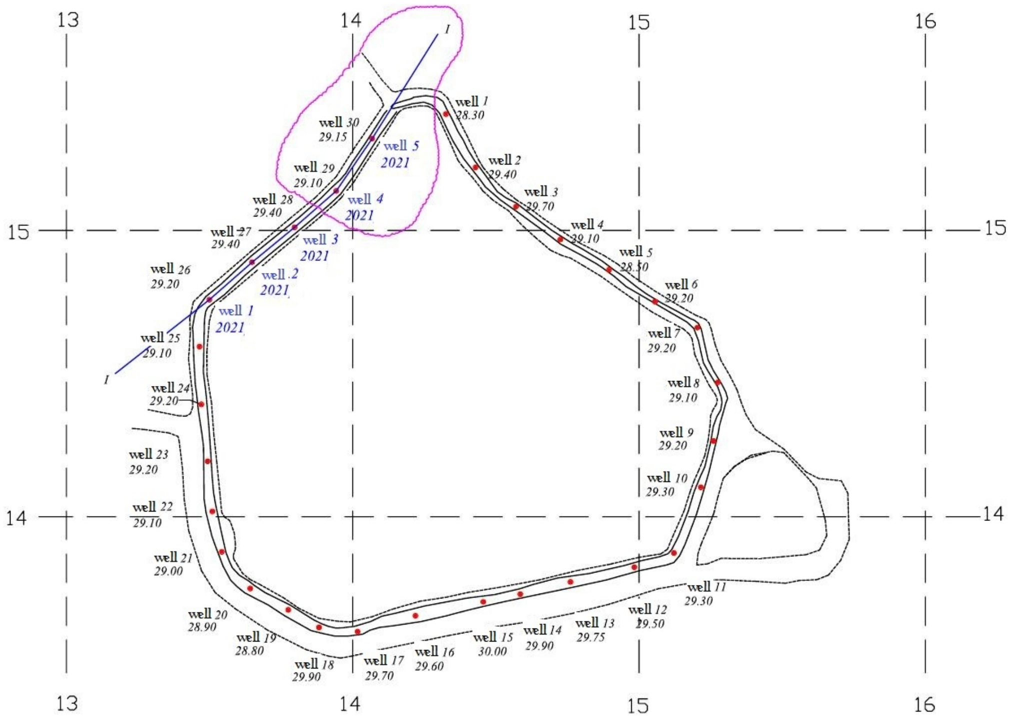


Figure 3 – Arrangement of wells of the engineering and geological surveys in 2021; violet line is a zone where lens of plastic consistency zone increases

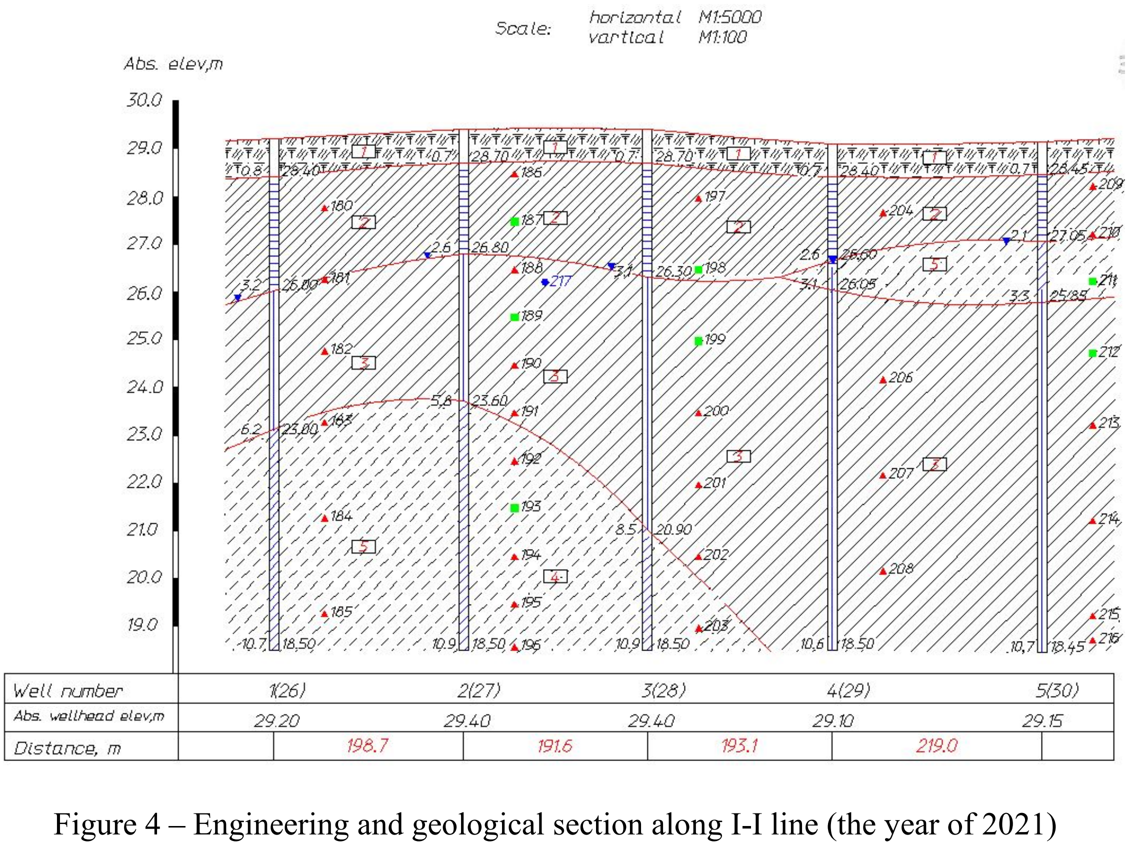


Figure 4 – Engineering and geological section along I-I line (the year of 2021)

To visualize the data, a comparative section was constructed on the inspection wells (Fig. 5).

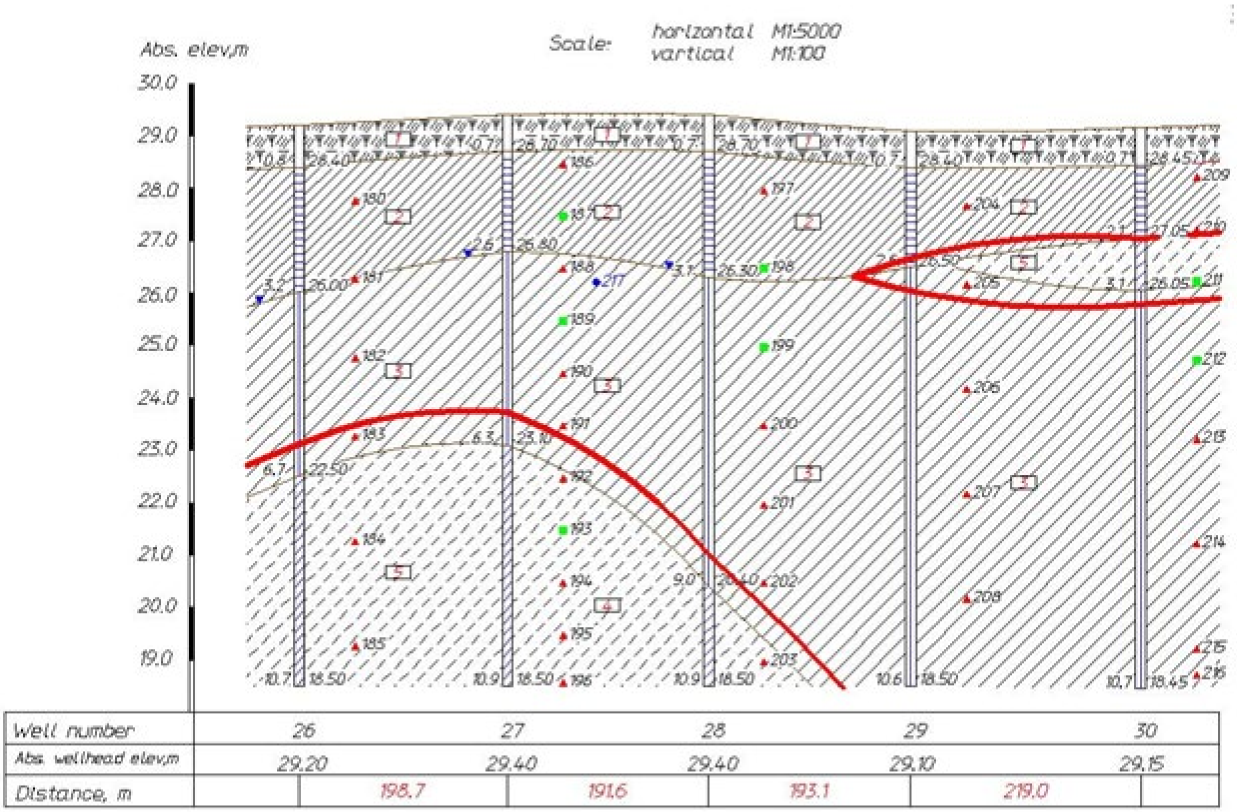


Figure 5 – Comparative arrangement scheme of the engineering and geological elements along the section (years of 2017 and 2021) where red line shows the data for 2021; and brown one shows the data for 2017

In the context of the section, a red line visualizes clearly the increased dimensions and thickness of plastic consistency sandy loam layer; the fact has a negative impact on geomechanical stability of the structure in general.

Comparison of the sections in terms of their coordinates made it possible to see progress of deformation processes in the enclosing rocks. Resulting from suffosion (i.e. technogenic water penetration through the dam), underwashing of rock layers takes place. Hence, the flow removes soluble substances and fine mineral particles from them.

Geomechanical stability of plastic consistency sandy loam is rather a complicated topic because of special behavior of the soil under load. Plastic consistency sandy loam is a soil consisting mainly of sand particles with inclusion of clay fractions influencing their strength, water permeability, and stability. Under load, plastic consistency sandy loam demonstrates low strength and tendency for deformation. Plasticity stipulates their ability for crackless deformation.

The plastic consistency sandy loams have several critical properties which may influence on their stability, namely:

- tendency for subsidence, i.e. high plasticity and significant compressibility under load may provoke nonuniform subsidence of structures;
- decrease in strength under water influence. Low shear stability makes the rock susceptible to shears which especially concerns slopes and additional load; and

- filtration deformations. Due to high permeability, water may favour removal of fine particles which results in formation of cavities and decrease in the overall stability.

To provide stability of such rocks, it is required to implement such specific engineering measures as drainage, chemical stabilization, compression, and reinforcement. Use of the integrated approach helps minimize risks, and ensure durability of structures built on such bases. However, determination of the optimum measures should involve detailed analysis of the facility, its structure and basis. Hence, archival data were analyzed which made it possible to identify peculiarities of the terrain and geological mass where the hydraulic structure was built. OldMaps software helped understand that the tailings pond is within a high-risk area where there are specific demands for research and preparation before the hydraulic structure is built. The matter is that the construction was performed on the site of the former lake; map of 1821 designates it as a Svinorekhove Lake (Fig. 6, a).

Later, when Kakhovka reservoir was being built, the territory was flooded during several years; the fact is confirmed by a map of 1953 (Fig. 6, b).

a) b)

Figure 6 – Excerption of cartographic materials of the site under study

Generally, wetlands shaped on the site of the former lake are of complicated geomechanical structure due to availability of water-saturated and loose soils:

- peaty soil. Organic peaty soil could be in the upper layers. The soil type is characterized by low bearing capacity; high compressibility; and considerable deformations under load;
- water-saturated sand. There were sand deposits in the lake. They can provoke a risk of soft ground and loss of stability while constructing. Geomechanical stability of water-saturated sand is quite an important characteristics for risk assessment during construction of hydraulic structures since the soil type has a number of specific characteristics influencing its ability to bear loads, and maintain stability; and
- silty soil. Rather often, the soil type is very loose, and demonstrates low shear stability.

Waterlogged territory of the former lake is connected with following risks:

− subsidence of a structure. Nonuniform subsidence are possible due to compressibility of organic and silty soil which can result in a structure deformation;

− stability of a basis. Soil types with low strength characteristics cannot bear weight of a hydraulic structure without specific reinforcement;

− shears. The site has a slope; hence, water-saturated soil can provoke shear risk;

− high water permeability. Availability of sand or fissured rock can result in water infiltration complicating construction of the structure as well as its operation; and

− hydrostatic pressure. Surplus water in soil may impose extra load on the structure basis.

Following design approach should be implemented for successful construction within the former lake wetland:

1. Basis strengthening, i.e.
   - loose soil replacement for tighter materials;
   - use of geotextile membranes, drainage systems or pile foundations; and
   - use of sand or gravel beds to decrease compressibility of the basis.
2. Drainage, i.e.
   - installation of a drainage system to lower a ground water level; and
   - use of water-removing channels to stabilize the area.
3. Load optimization, i.e.
   - engineering of a structure with minimum load on its basis; and
   - use of light materials for building operations.
4. Construction monitoring, i.e.
   - constant control of subsidence, displacements, and water level.
5. Long-term control, i.e.
   - installation of monitoring systems to assess the structure state during its operation.

Analysis of the available materials and archive data helped made a conclusion that no one of the requirements was met sufficiently; moreover, certain requirements were ignored.

After the tailings pond construction and during operation period, the dam turned out to be under constant change in soil water saturation resulting from water level variation (i.e. it was either full of water or dry completely). The fact is supported by Google Maps satellite images captured in different years (Fig. 7).

Analysis of the monitoring data helped obtain actual information as for the current facility state, and zones of potential problems. The information makes it possible to make decision concerning further actions. Following measures should be implemented under the current conditions within the studied territory. First of all, it is recommended to take drainage, anti-filtration, and water-removal steps. In addition, it is required to perform measures preventing from water-logging, bogging, and polluting territory outside the tailings pond. Moreover, the rules of surface water protection against contamination should also be adhered.

In view of the fact that such engineering and geological operations as well drilling are expensive techniques for data collecting and facility monitoring, it is proposed to monitor through ground benchmarks since it is rather important measure to control stability and behaviour of the structure as well as adjoining soil (Fig. 8).

Figure 7 – Excerption by years of the tailings pond fullness

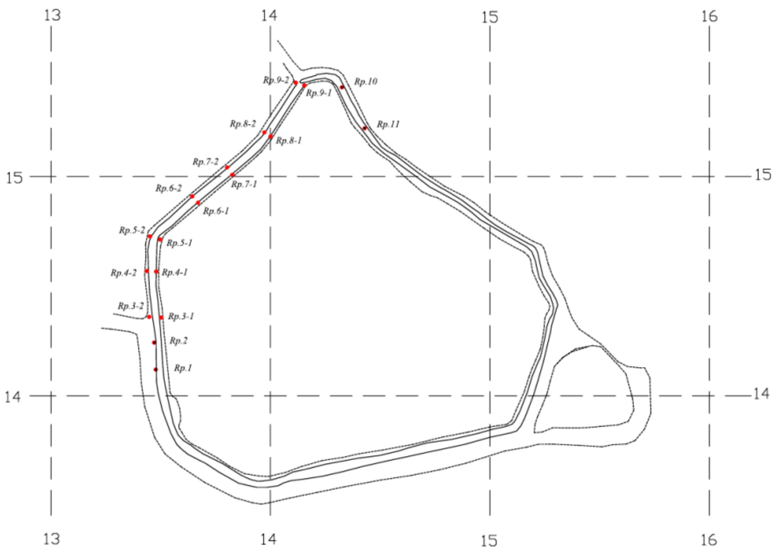


Figure 8 – Arrangement scheme of observational monumental benchmarks

It is proposed to set the monumental benchmarks within the dam sites, namely in the area where a layer of sandy rocks differing in plastic consistency becomes thicker, i.e. set two lines of the benchmarks in accordance with the proposed scheme (see Fig. 8).

The set in the ground monumental benchmarks help identify accurately the coordinates to calculate displacement, subsidence, and the object deformation over time. The monitoring makes it possible to show dangerous tendency, which may impact the facility stability. This is especially true for causes when hydrostatic pressure or erosion impacts (as in our case).

Analysis of the obtained data helped assess the structure stability as well as its separate parts. If considerable displacement or subsidence is observed then it may be a signal to carry out additional research or perform activities for basis strengthening. Relying upon the data collected using the ground benchmarks, it is possible to forecast further deformation progress, and define potential risks for the structure. The abovementioned helps make timely decisions concerning maintenance or strengthening operations. Taking into consideration displacement tendencies, it is possible to forecast how long the structure will operate safely before critical condition happens which helps plan its maintenance or modernization.

Following measures are taken to avoid suffusion:

- limitation of flow and water movement in rocks: land run off is regulated and underground water is caught by means of drainage systems;
- protection of clay rocks against weathering while laying protective sand or mixed clay layers;
- installation of surface drainage systems to remove water, and avoid elution of particles; and
- deceleration of underground water flow through changes in a structure design. For example, clay blankets can be installed under dams to continue filtration process and reduce water head.

4. Conclusions

Owing to the set of field observations (both visual and instrumental), it became possible to identify zones of a tailings pond dam differing in non-homogeneous structure; a laminar filtering zone; and rock lens of plastic consistency. It was substantiated that the zones need attention since they are connected with previous manifestation of hidden processes; ultimately, they result in origination of such negative phenomena as subsidence, cracks, failures etc. Among other things, they depend upon disturbance of filtration, water-removal, and damp-proof modes.

It was proved that the performed set of field observations helps control parameters of zones with negative processes as well as deformation progress in the rock mass. Reasons of plastic consistency rock lens in the dam and geomechanical instability of the structure was studied. Scheme of arrangement of benchmarks within the dangerous dam area was proposed for further monitoring of deformation processes.

Analysis of geomechanical stability of the tailings pond makes it possible to assess accurately its ability to withstand loads and identify potential hazards. Owing to the efforts, the opportunity arises to take preventive measures; avoid accidents; and provide safety for structures and adjoining territories. Such an analysis helps maintain high reliability of hydraulic objects during their continuous operation.

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РЕЗУЛЬТАТИ МОНІТОРИНГУ СТАНУ ДАМБИ ТА ОБҐРУНТУВАННЯ ПРИЧИН ДЕФОРМАЦІЇ ДІЛЯНКИ ХВОСТОСХОВИЩА

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Анотація. Метою роботи є аналіз результатів комплексу інженерно-геологічних вишукувань діючого хвостосховища для визначення небезпечних ділянок дамби та встановлення причин розвитку деформаційних процесів в дамбі задля розробки заходів щодо геомеханічної стійкості споруди.

У тексті наведені досвід і результати перевірки стану діючого хвостосховища, в якому зберігаються шлами збагачувальної фабрики. Об'єктом досліджень є дамба хвостосховища «Криві Луки» ПАТ «Орджонікідзевський гірничо-збагачувальний комбінат».

Проаналізований світовий досвід аварій на дамбах хвостосховищ та всі можливі причини виникнення аварій. Доведено, що потенційно небезпечні процеси і явища протікають в середині масиву. Обґрунтована необхідність виконання моніторингу геомеханічної стійкості гідротехнічної споруди.

Моніторинг виконувався у декілька етапів, що дозволило прослідкувати динаміку процесів. За результатами первинного буріння свердловин було виявлено ділянки дамби хвостосховища з деформаційними процесами, а саме зони однорідних насипних глин, зона ламінарної фільтрації техногенного походження, зона неоднорідної будови дамби. Через чотири роки на цих ділянках було виконано буріння нових контрольних свердловин. Після обробки кернів визначилось значне збільшення розмірів лінзи супіщаних порід пластичної консистенції, яка впливає на розвиток деформаційних процесів в дамбі. Для встановлення причин розвитку геомеханічно нестабільної зони були досліджені гірничо-геологічні, гідрогеологічні та інженерно-геологічні умови використання споруди. Встановлено, що проблемна ділянка дамби розташована вздовж балки, земельна ділянка під спорудою історично була затопленою багато років, геологічна будова масиву, що є основою хвостосховища, не була підготовлена для будівництва гідротехнічної споруди. Запропоновано для збільшення ефективності подальшого моніторингу закласти ґрунтові репери на ділянках дамби саме в зоні збільшення потужності шару супіщаних порід пластичної консистенції.

Ключові слова: гідротехнічна споруда, моніторинг технічного стану, геомеханічна стійкість, деформації, хвостосховище.