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# Application of prefabricated retaining walls with increased shear resistance to ensure tailings dam stability

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**Abstract.** Tailings ponds and sludge storage facilities do not currently meet modern standards that regulate the requirements for operational safety, reliability, stability and durability. The research considers new constructive solutions for retaining walls with increased shear resistance due to passive soil resistance. Schemes and designs of tailings dams are analyzed. A comparative analysis is carried out using recommended methods to determine the safety factor for the design slip curves. The regularities of the influence of multilayer nonlinearly deformed backfill and external loads are established and new principles for determining the horizontal pressure on the retaining wall are formulated. The development of new design solutions for retaining walls and calculation methods for determining the lateral pressure of multilayer backfill is an urgent scientific task. Consideration of the influence of a multilayer nonlinearly deformed massif under external loading allows formulating new principles for determining the horizontal pressure on the retaining wall.

## 1. Introduction

Accumulation of a significant amount of industrial waste is associated with the development of the mining and metallurgical industry in Kryvyi Rih. The volumes and areas of production sludge and concentration tailings have grown considerably over the long term of operation. This negatively affects the state of technological and environmental safety and worsens the environmental situation in the adjacent areas [1–5].

Tailings ponds and sludge storage facilities do not currently meet modern standards that regulate the requirements for operational safety, reliability, stability and durability as they were designed in the last century [6, 7].

Application of retaining walls is proposed to prevent or avoid the negative engineering conditions of dams and embankments.

In the practice of designing retaining walls, no engineering method has been developed that takes into account the multilayer nature of the foundation in the presence of surface loads. The existing methods of H.K. Klein and other authors cannot be used because each layer of heterogeneous backfill, when taking into account the weight of the soil, has its own most unfavourable slope angle of the sliding planes, and the patterns of pressure distribution in the



massif caused by different types of payloads have not yet been found. Therefore, even the simplest superposition method, which allows summarizing the pressure caused by the soil and the loads on the surface, remains technically unfeasible for multilayer soil.

Current engineering practice assumes that loads outside the traditional prism of failure do not affect the retaining wall, but this is not true and can lead to accidents.

The development of new design solutions for retaining walls and calculation methods for determining the lateral pressure of multilayer backfill is an urgent scientific task.

## 2. Research objectives

The aim of the research is to ensure the stability of tailings dams by using the proposed prefabricated retaining walls with increased shear resistance during the multilayer backfill build-up and operation of the structure.

To achieve this, the following tasks should be solved:

- to conduct an analytical review of the schemes and designs of tailings dams;
- to conduct a comparative analysis using the recommended methods to determine the safety factor for the calculated sliding curves;
- to develop a new design of the retaining wall to ensure the stability of the enclosing dams;
- to formulate new principles for determining the horizontal pressure on the retaining wall, considering the multilayer backfill and the load on the surface.

## 3. Results

In recent years, significant experience has been gained in the operation of storage facilities and the construction of dams and embankments made of waste and overburden.

Any type of storage capacity, except for pit and basin ones, requires the construction of enclosing dams or embankments that are washed from waste materials or filled with overburden or local soils. Depending on the technical conditions, enclosing dams or embankments can be built to their full height at once or in stages.

All existing storage facilities are divided into two types depending on the type of structures:

- dammed (filling) facilities, in which enclosing structures are erected at once to the full height or in stages;
- gradual construction storage facilities, in which a primary dam of low height is first constructed to arrange backwash, and then the storage facility is increased in height by gradually constructing secondary dams;
- damless facilities, which exclude the construction of both the embankment and the primary dam.

Depending on the terrain, the following types of storage facilities are distinguished:

- ravine dams located in ravines or gullies blocked by a dam;
- plain facilities arranged on flat ground and dammed around the entire perimeter. The operational advantage of a plain storage facility is that there is no need to discharge natural runoff and build expensive spillway structures for this purpose;
- ravine and plain facilities built on plains crossed by ravines, which are blocked by a dam, and the plain is dammed;
- floodplain facilities located on river floodplains and dammed on two or three sides, depending on the terrain;
- slope dams arranged in areas and enclosed by dams on three sides and the slope itself on the fourth;

- pit storage facilities located in dead pits, and waste can be stored without building a dam;
- basin storage facilities located in basins, where waste can be stored without a dam or a low-height dam is required.

The type of enclosing dams for the storage facility is determined depending on the availability of certain soils in the immediate construction area, the construction method, engineering, geological and hydrological conditions of dam foundations, and the capacity of the concentration plant at the mining and concentration works.

The same soils can be used to construct enclosing dams as for the construction of water retention dams and embankments, as well as waste discharged by concentration plants.

There are two ways to fill a storage facility: from the dam or the embankment to the banks and from the bank to the dam or embankment, and in the case of a plain storage facility, the dam is filled by pools. Three methods of waste inwash into in dams and embankments are recommended – trestle, zenithal and trestleless.

To construct dams and embankments, overburden and waste from concentration plants, as well as various local construction materials should be used as much as possible, specifically sand, clay soils, crushed stone, gravel, stone, etc. Soils for dam construction should meet the requirements of the standard for the design of dams made of soil materials [8].

The Mining and Concentration Plant ArcelorMittal Kryvyi Rih is an operating iron ore mining and concentration facility located in the southern part of Kryvyi Rih.

Tailings are stored alternately in Obiednane and Myroliubivka tailings ponds, which are located to the south and southeast of the central industrial site, respectively.

The operation of Myroliubivka tailings pond with a build-up layer up to the level of the 135 m and above is distinguished by an alternating block system of construction and pool washing.

First of all, the cells of the southern block (№ 6, 7-8, 9-10, and 11) are built and washed out. The northern block includes pools 1-2, 3-4, and 5. These pools are built and washed out in the second turn, and the duration of the construction of the northern block of pools is determined by the time of washing out the southern block of pools.

The Additional Compartment pool is also washed out, but its washing out period does not depend on the washing out of other blocks.

The main focus of the inspection was on the most hazardous area of the tailings pond, namely the area between S38 and S41. It required reconstruction as a result of lost stability, negligent operation and increased moisture of soils.

The design of the general tailings dam is a combined one, consisting of embanked secondary belt dams and an “washed in retaining prism” made of tailings.

The Myrolyubivka tailings pond is classified as a capital class 1 facility in terms of its capacity, overall height and degree of responsibility.

Structurally, Myroliubivka tailings facility currently consists of a primary loam dam from the crest level of 102.5 m and secondary dams are being built up at 108.5 m, 115.0 m, 120.0 m, 125.0 m, 130.0 m and 135.0 m levels. The entire perimeter of the tailings pond was previously filled with downstream surcharge: for the most part the tailing pond up to the level of 103.0 m, in the vicinity of spillway 3 – up to the level of 111.0 m.

The primary dam is constructed of loam with a retaining prism and rock overburden support. At 108.5m, 115.0 m and 120.0 m, the dams are structurally a rock prism with a tailings face. Modern man-made (rock-fill and hydraulic) formations, namely waste dumps, raise of dams, roads, sludge in tailings ponds, etc. play a significant role in the geological structure of the area. The thickness of these formations is often measured in tens of meters.

Myroliubivka tailings pond is located on Velyka Krokva gully, its slopes and adjacent areas. Velyka Krokva gully flows into Hrushevata gully.

The area around tailings ponds is built up with technological facilities and communications. Temporary man-made (rock-fill and hydraulic) formations, such as waste dumps, walls of

embankments and dams, roads, sludge in tailings ponds, etc., play a significant role in the geological structure of the area. These formations are often tens of meters high.

Beneath the man-made formations in the tailings pond area under investigation are Quaternary accumulations represented by alluvial-deluvial loams, less often clays (containing organic matter), a loess-like thickness of yellow-brown and pale sandy loams, two levels of dark brown (slightly humus), red-brown loams and clays in the gullies.

The thickness of Quaternary accumulations is highly variable and reaches 20.0-23.0 m in some places. These formations are underlain by Neogene sediments of the Pontic and Sarmatian levels. Below are the Paleogene deposits, which are based on weathered crystalline rocks of the Paleozoic-Cenozoic period.

The depth of groundwaters and Quaternary sediments occurrence varies widely from 0.5-1.0 m to 10-15 m. In the tailings ponds, these groundwaters are of a pressure nature. In some places, the pressure reaches tens of meters.

The waters are highly mineralized and hard, ranging from slightly aggressive to highly aggressive towards concrete.

To control the quality of the washed in tailings, the Geotechnical Control Service (GCS) took 185 samples in 23 boreholes (figure 1) on the beaches at the dike at the 140.0 m level. The monitoring time of the control and measuring equipment (CME):

- at the dam crest elevation of 140 m, 12 cycles were performed between January and December;
- at the dam crest elevation of 135 m, 1 cycle was conducted in August;
- at the 130-meter crest elevation ("Additional Compartment"), 7 cycles were conducted between January and August;
- at the 130-meter dam crest elevation, 1 cycle was conducted in September;
- at the 125-meter dam crest elevation, 1 cycle was conducted in October;
- at the 120-meter crest elevation, 1 cycle was conducted in October;
- at the 115-meter crest elevation, 1 cycle was conducted in October.

The laboratory studies determine granulometric composition of tailings.

Based on the results of CME instrumental inspections and a comparison with the previous year's results, we can conclude that there is a uniform increase in subsidence. This is due to intensive beach erosion and active construction of 140.0 m dikes.

Along the perimeter of the tailings pond, 14 CME dam site are installed on the dike from the at the crest level of 140.0 m, and 6 CME sites – in the area of the Additional Compartment at 130.0 m. Based on the results of the measurements, graphs of subsidence are built (figure 2, figure 3, figure 4, figure 5).

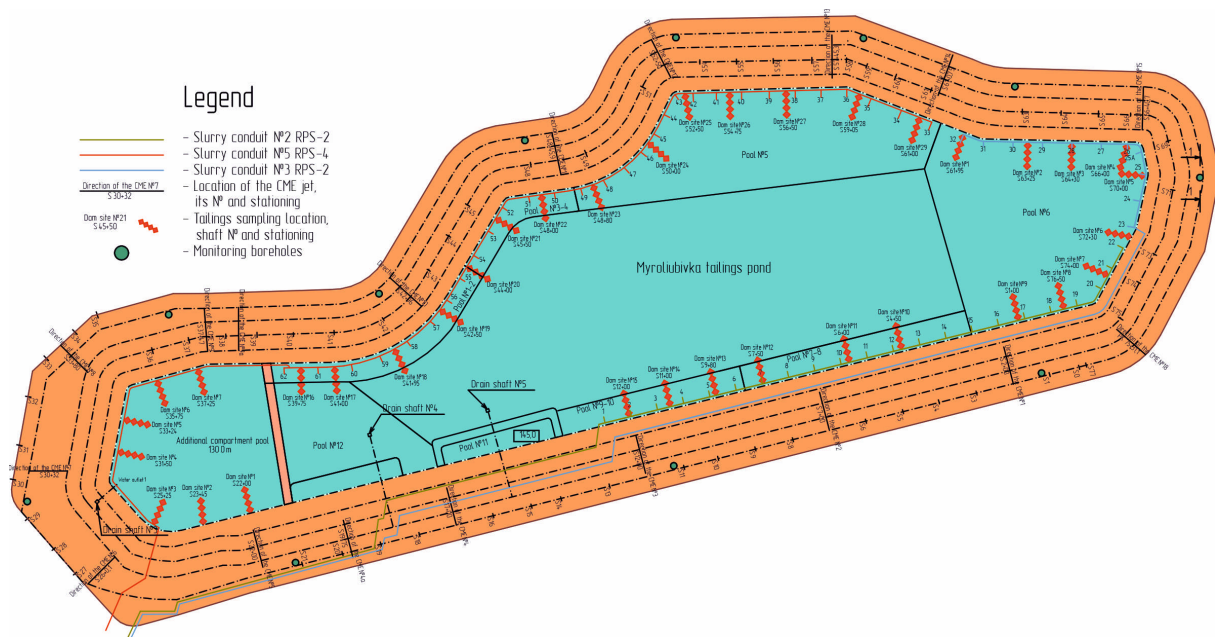
To monitor the depression curve, water levels are measured quarterly in piezometers (figure 6) installed on the dams at 115.0 m, 120.0 m, 125.0 m, 130.0 m and 135.0 m crest levels.

A system of drainage devices is installed to improve the reliability of the dike operation to reduce the level of the depression curve, prevent its release onto the downstream slopes and avoid pollution of surface and groundwater.

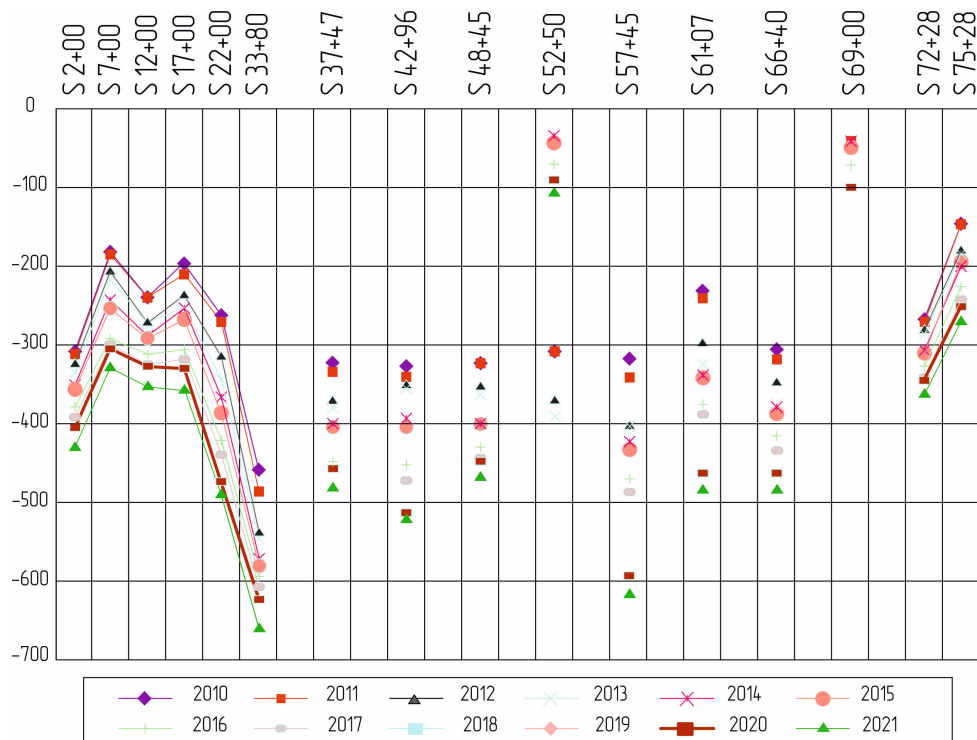
Calculations aim to assess the tailings pond condition, ensure regulatory stability during the increase of the enclosing dams to the 140.0 m level of the tailings pond and propose additional measures to ensure the required reliability during operation.

The reliability of a storage facility is understood as a complex property that consists in its ability to perform the functions of a waste storage tank under specified operational, structural, and environmental safety indicators during the estimated period of time.

Strength and stability of modern hydraulic facilities are assessed by the limit state method, according to which all the initial design values, which are random in nature, are represented by



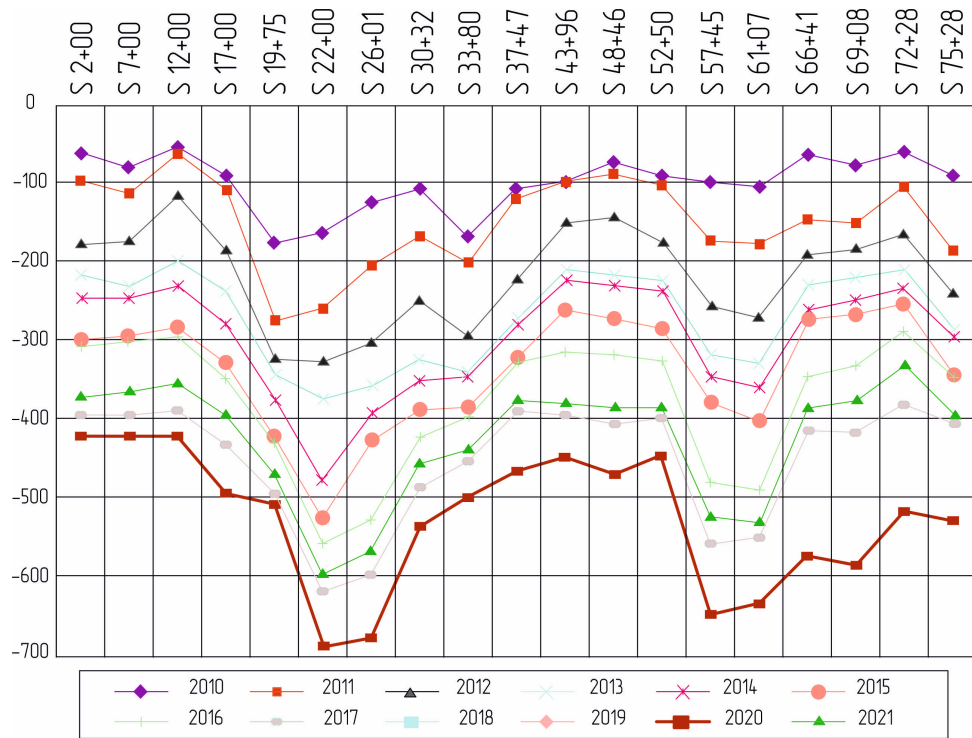
**Figure 1.** Tailings sampling plan for Myroliubivka tailings storage facility.



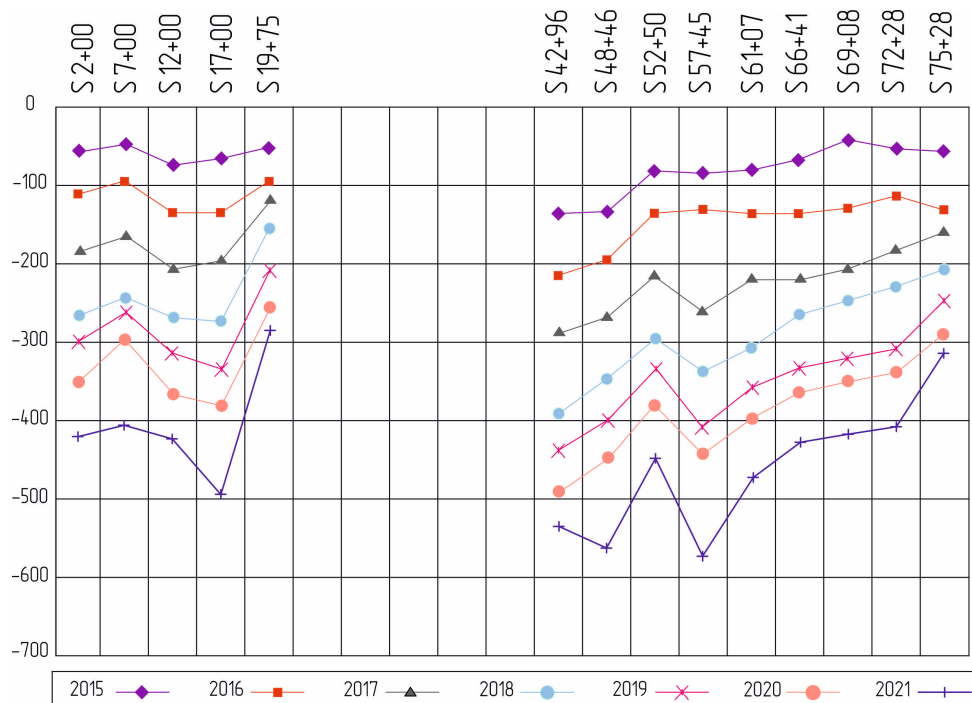
**Figure 2.** Subsidence diagram CME by the 120 m dike overflow levels.

some deterministic values, and the impact of this variability on structure reliability is taken into account by relevant coefficients regulated by the standards.

In the case of storage facilities, it is very difficult to consider all the randomness and uncertainties using deterministic coefficients.

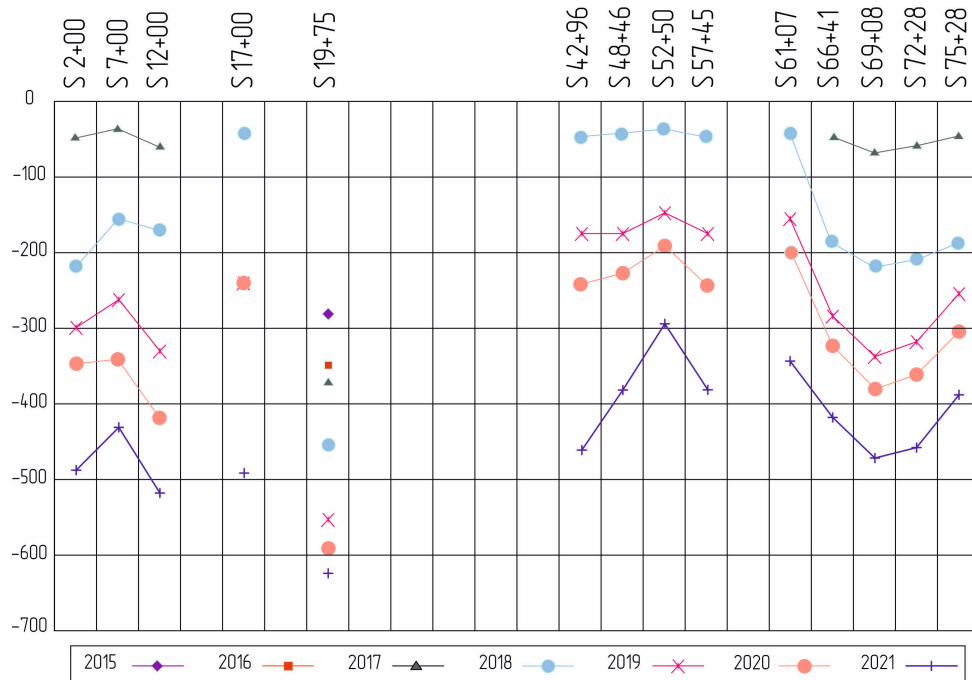


**Figure 3.** Subsidence diagram CME by the 125 m dike overflow levels.

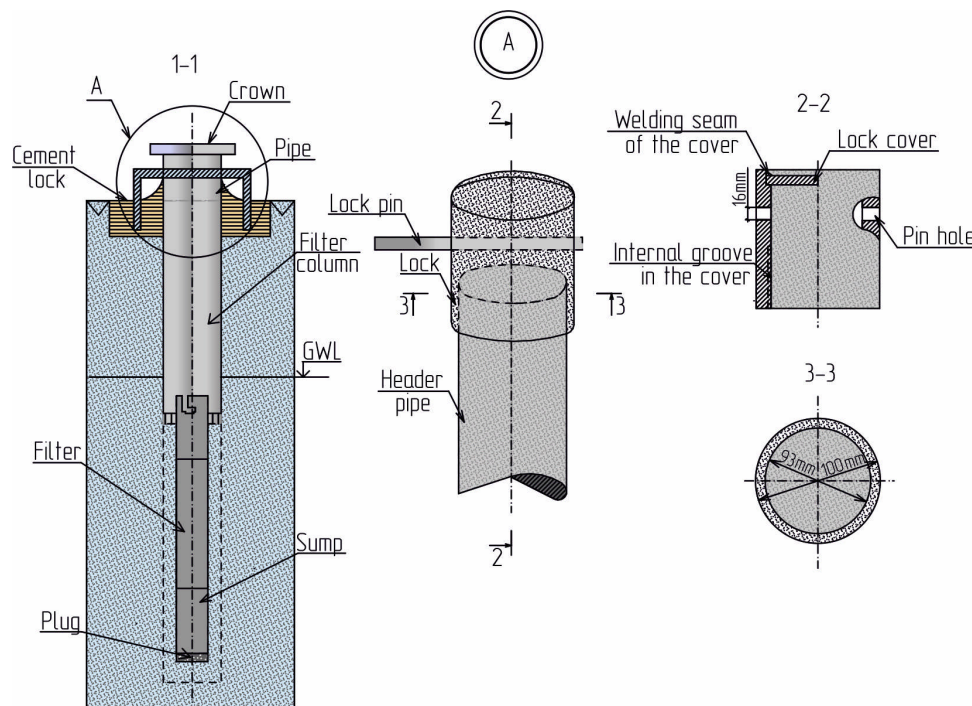


**Figure 4.** Subsidence diagram CME by the 130 m dike overflow levels.

As a rule, pressure structures of storage facilities are embankments of a complex layered structure, the soils and materials of which are characterised by significant variability of



**Figure 5.** Subsidence diagram CME by the 135 m dike overflow levels.



**Figure 6.** Design of observation boreholes.

characteristics, including time variability. In addition, the specificity of the storage facility is a change in their main technological parameters (elevation, impact area, etc.) during their service life, which, taking into account other factors and features mentioned above, introduces significant uncertainty into each of the indicators characterising the facilities' condition.

Considering that the designed tailings pond is a hydraulic structure, the material for which is the waste (tailings) stored in it, the reliability of the structure and the possibility of emergency situations depend on the quality of tailings alluviation and compliance with the specified design parameters (both physical and technological).

The following design case was considered for the stability of the downstream slope of Myroliubivka tailings pond (for all cross-sections): no water in the downstream, normal retaining level (NRL) in the upstream is assumed to be at its maximum position, and the dam body is considered to have installed filtration for the maximum design water level.

The following design cases are considered in determining the stability of the hydraulic dam in the vicinity of spillway 4:

- for the downstream slope – the main load combination; a dam with the 135.0 m crest, normal retaining level in the upstream, and filtration installed in the dam body;
- for the upstream slope, the construction period is designed: the main protection dam and the dams of the pools with the 135.0 m crest (at the end of washing out the last layer of the pools). The water level of the clarification pond (in the pool) is at 134.3m, the level of sludging the upstream slope with tailings is 133.75m), and filtration is installed in the dam body. At the base of the hydraulic dam, the tailings pond is washed out up to 121.6 m; the water level is at 122.5 m.

In determining the dam stability in the vicinity of spillway structure 3, the following design case is considered. As for the main load combination, the dam has a 125.0 m crest, a normal retaining level (123.5 m) in the upstream, and filtration in the dam body.

The dam stability is calculated by two programmes: the computer aided design system for ground hydraulic structures and the KZU86K programme developed by specialists of the VIOGEM Institute (the All-Russian Research Institute for Mineral Deposits Drainage, Protection of Engineering Structures from Flooding, Special Mining Works, Geomechanics, Geophysics, Hydrotechnics, Geology and Mine Surveying).

The computer-aided design system for soil hydraulic structures (CAD SHS) is designed to solve a number of problems in designing dams, dikes, upland ditches, sludge ponds, tailings dams and other structures [8].

The Terzaghi method provides lower safety factors for gentle slopes (1:2 or more), with a difference of 10...20%. The averaged slopes of Myrolubivka tailings pond are much gentler.

The desire to take into account all equilibrium conditions in the shear scheme leads to the emergence of such methods as the Mozhevytnov method (method of inclined interaction forces) and the finite element method (FEM).

The Terzaghi-Chuhaiev calculation method gives results intermediate between the Terzaghi and Chuhaiev methods. In accordance with the regulatory literature, the methods adopted in this study are allowed to be used in calculations.

All the described calculation methods refer to the case of a plane problem, i.e. it is assumed that no resistance forces occur along the lateral parts of a single slip or retaining prism along the front of the structure. In reality, slope failures are usually local and have a closed contour in plan view. Taking into account the spatial extent of sliding for conditions that are not variable along the length (front) of the structure leads to an increase in stability coefficients, and therefore, in these cases, solutions of the plane problem are usually used, which are included in the “stability margin”.

The software allows performing stability calculations using the following methods:

- Terzaghi weight pressure method;
- Mozhevytnov method of inclined interaction forces, recommended by the standard;
- FEM (the finite element method).

The programme also allows performing filtration calculations necessary for calculating slope stability.

Filtration calculations determine the following parameters of the filtration flow:

- position of the filtration flow surface (depression surface);
- filtration water flow through the body of the structure and its foundation;
- pressure gradients of the filtration flow in the body and base of the structure at the boundaries of soils and media.

Filtration calculations are performed in accordance with the following regulatory documents.

Filtration calculations are performed using the FEM method based on the methodological recommendations for calculating the safety factor of slopes with a circular-cylindrical sliding surface using the KZU86K programme.

The programme allows defining a set of design slip curves (with safety factors) in a given slope range. This makes it possible to define both “general” and “local” slip curves.

Tasks solved by the programme include:

- determining the safety factor of the slope of the soil massif assuming arbitrary and circular-cylindrical sliding surfaces under static and seismic conditions, taking into account possible concentrated loads and pore pressure;
- determining all force characteristics for the selected sliding section (active and reactive forces on the covering footwall, column weights, distribution of filtration forces, etc.);
- solving the inverse problem (at a given stability factor of 1, it is determined by the strength of the slope soil property).

To obtain the desired result, a calculation algorithm is developed:

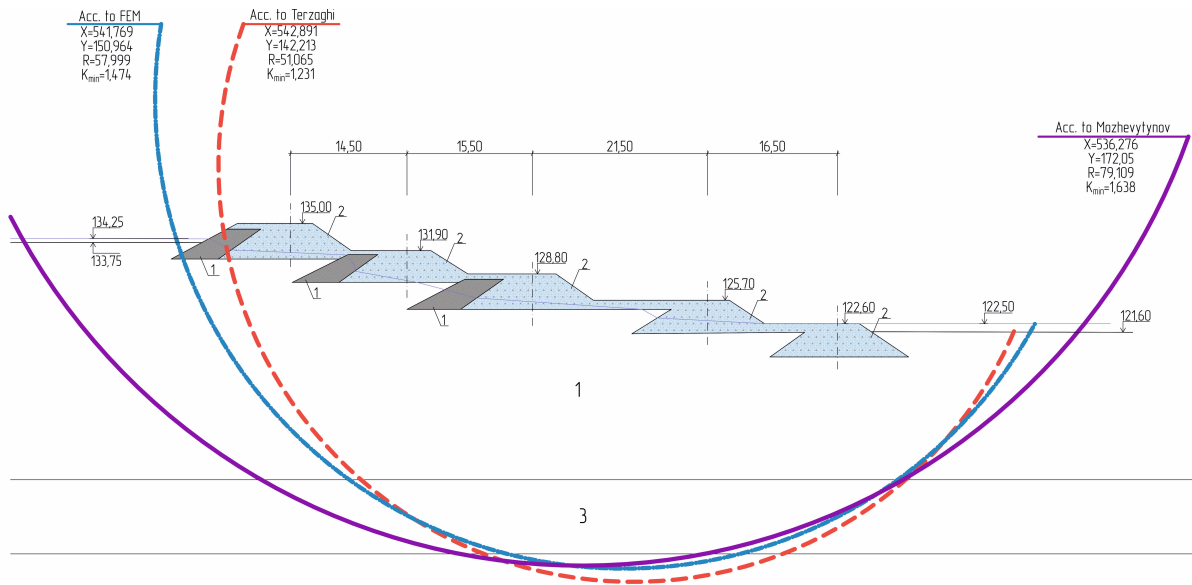
- select design materials for the construction of design diameters;
- draw geological sections on cross-sections;
- analyse the results of geological data and selected design characteristics;
- encode initial data for calculation for all cross-sections and interpret the geological data;
- enter the information into the calculation software;
- perform primary calculations using 4 methods (ITU, Mozhevytnov, Terzaghi, and Terzaghi-Chuhaiev) and 2 programs (CAD SHS, KZU86K) for all the dam sites (for the “general” curve and “local” curves);
- select the contours of additional loading of the downstream slope with intermediate calculations;
- analyse the results obtained.

The results of stability calculations are expressed as slip curves on the cross sections of Station (S) 39+00 (upstream and downstream slope) (figure 7, figure 8).

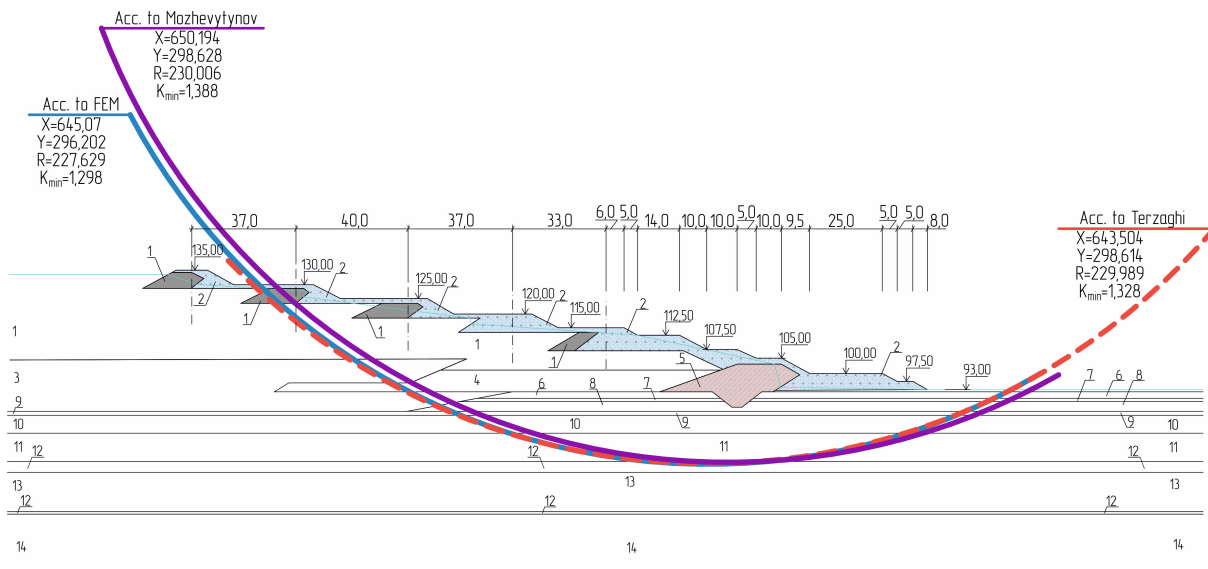
The results of calculations of the stability of the downstream dam slopes, with the selection of minimum safety factors determined for the “general” curve, are shown on the design sections.

The minimum safety factors of the “general”/“local” curve for the main combination of loads in the calculation of the stability of the lower slopes of dams are as follows:

- for S 8+50 according to the methodology: Mozhevytnova (1.501 / 1.568), FEM (1.522 / 1.423), Terzaghi (1.417 / 1.45), Terzaghi-Chuhaieva (1.53 / 1.58);
- for S 19+00 (upper) by methods: Mozhevytnova (1.638 / –), FEM (1.474 / –), Terzaghi (1.231 / –), Terzaghi-Chuhaieva (– / –);



**Figure 7.** Results of stability calculations (upstream slope of the S 39+00 cross section): 1 – silt washed-in tailings; 2 – rocky overburden; 3 – loam washed-in tailings.



**Figure 8.** Results of stability calculations (downstream slope of the S 39+00 cross section): 1 – silt washed-in tailings; 2 – rocky overburden; 3 – loam washed-in tailings; 4 – small washed-in tailings; 5 – filled soil – clay in the body; 6 – loess, heavy, silt, red-brown loam; 7 – hidden soil, silt heavy loam; 8 – loess, heavy, silt, yellow-brown loam; 9 – hidden soil, heavy loam; 10 – heavy, red-brown loam; 11 – light, silt, ocher-red clay; 12 – heavy, silt, green-gray clay; 13 – fine sand with a layer of loamy sand and loam; 14 – light, green-gray, light gray clay.

- for S 19+00 (lower) by methods: Mozhevytnova (1.388 / -), FEM (1.298 / -), Terzaghi (1.328 / -), Terzaghi-Chuhaieva (- / -);
- for S 24+25 by methods: Mozhevytnova (1.5 / 1.488), FEM (1.471 / 1.484), Terzaghi (1.437 / 1.411), Terzaghi-Chuhaieva (1.49 / 1.42);

- for S 27+50 by methods: Mozhevytnova (1.265 / 1.048), FEM (1.208 / 1.166), Terzaghi (1.143 / 1.055), Terzaghi-Chuhaieva (1.26 / 1.27);
- for S 31+00 by methods: Mozhevytnova (1.366 / 1.551), FEM (1.335 / 1.527), Terzaghi (1.313 / 1.44), Terzaghi-Chuhaieva (1.37 / 1.58);
- for S 33+80 by methods: Mozhevytnova (1.785 / 1.618), FEM (1.871 / 1.630), Terzaghi (1.722 / 1.503), Terzaghi-Chuhaieva (1.71 / 1.38);
- for S 34+60 by methods: Mozhevytnova (1.637 / 1.003), FEM (1.601 / 0.98), Terzaghi (1.576 / 0.888), Terzaghi-Chuhaieva (1.66 / 1.08);
- for S 42+96.6 by methods: Mozhevytnova (1.553 / 1.444), FEM (1.494 / 1.561), Terzaghi (1.501 / 1.53), Terzaghi-Chuhaieva (1.52 / 1.51);
- for S 51+60 by methods: Mozhevytnova (1.742 / 1.218), FEM (1.726 / 1.25), Terzaghi (1.667 / 1.08), Terzaghi-Chuhaieva (1.55 / 1.53);
- for S 55+25 by methods: Mozhevytnova (1.477 / 1.626), FEM (1.427 / 1.585), Terzaghi (1.428 / 1.487), Terzaghi-Chuhaieva (1.53 / 1.46);
- for S 61+07.5 by methods: Mozhevytnova (1.554 / 1.505), FEM (1.498 / 1.475), Terzaghi (1.462 / 1.445), Terzaghi-Chuhaieva (1.49 / 1.5);
- for S 69+02.2 by methods: Mozhevytnova (1.471 / 1.49), FEM (1.561 / 1.645), Terzaghi (1.437 / 1.433), Terzaghi-Chuhaieva (1.62 / 1.65);
- for S 72+60 by methods: Mozhevytnova (1.622 / 1.738), FEM (1.62 / 1.753), Terzaghi (1.565 / 1.582), Terzaghi-Chuhaieva (1.62 / 1.52).

In calculations of the stability of the downstream dam slopes of dams, the position of the depression curve (the position of the filtration flow surface) is taken on the basis of CAD SHS-based filtration calculations.

A comparative analysis of the calculation results of the stability of the downstream slopes shows comparatively close values of the obtained coefficients and the correctness of the choice of calculation methods as the most commonly used in practice.

Analysis of the actual condition of hydraulic structures, taking into account the calculations performed, drawing the following conclusions about Myroliubivka tailings storage facility:

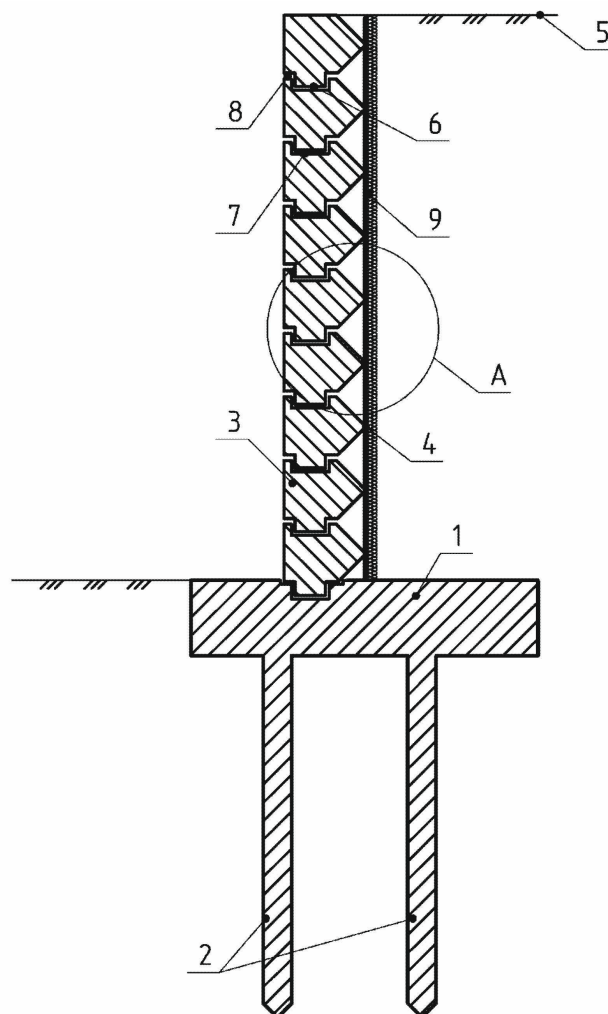
- The reliability of the downstream slope of the tailings dam at Myroliubivka tailings storage facility is assessed in accordance with regulatory requirements;
- Most calculated cross-sections, according to all the methods used to calculate the downstream slope, have a safety factor (both for general and local stability) that is higher than the minimum required by the standard;
- For certain cross-sections, minimum safety factors determined are less than the required standard values. For these sections, additional measures to ensure standard stability are required;
- According to the standard, Kryvyi Rih is classified as an area with a seismic intensity of 6 points. Soil conditions at Myroliubivka tailings pond are classified as category III. At the same time, the overall seismicity of the area is 6 points and it does not fall within the seismicity standard. On this basis, no seismic stability checks are performed at this stage of work.

Recommended measures include:

- All hydraulic structures of Myroliubivka tailings facility should be subjected to constant monitoring of the dam condition, compliance with design requirements for tailings allocation technology, the degree of wear of pipelines (especially those passing through dams and in the vicinity of hydraulic structures), and compliance with design water levels in the tailings facility;

- To ensure the required reliability of the tailings facility, it is proposed to construct a special type of retaining wall in the area with the lowest safety factor for the period of dam operation [9, 10].

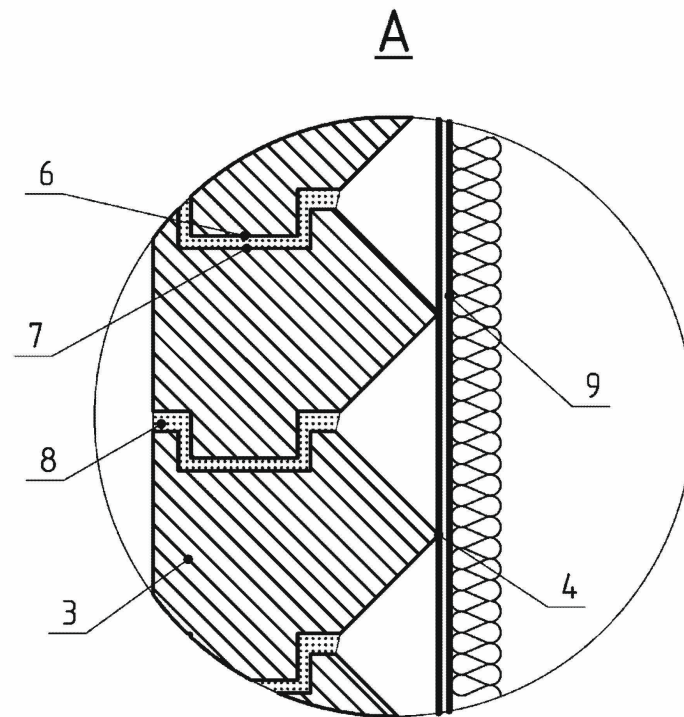
The proposed prefabricated block-type retaining wall (figure 9, figure 10) consists of a foundation slab and a vertical element presented in the form of concrete or reinforced concrete blocks mounted on top of each other, the front face of each of them is made straight, and the back face is in the form of a structural surface of pyramids. The foundation slab of the retaining wall is equipped with piles located directly under the base of the foundation slab.



**Figure 9.** Prefabricated block type retaining wall: 1 – foundation slab; 2 – piles; 3 – blocks; 4 – surface in the form of pyramids; 5 – soil; 6 – spikes; 7 – groove; 8 – high-strength solution; 9 – two sheets of flexible, resilient material.

To prevent premature filling of the cavities, two flexible separating sheets of elastic and pliable material made of a biodegradable polymer are placed on the back surface of the vertical element.

The proposed prefabricated block-type retaining wall consists of a foundation slab 1 with piles 2 and a vertical element made of blocks 3 stacked one on top of the other. The vertical element includes front and back faces. The front face of blocks 3 is rectilinear, and the back face is in the form of a structural surface, which is a protruding pyramid 4 from the side of retained



**Figure 10.** Node A: 3 – blocks; 4 – surface in the form of pyramids; 6 – spikes; 7 – groove; 8 – high-strength solution; 9 – two sheets of flexible, resilient material.

soil 5. The blocks are mounted one on top of the other and interconnected by spikes 6 that fit into grooves 7 on high-strength mortar 8. On the back face of the vertical element, there are two sheets of flexible, resilient material 9 made of biodegradable polymer.

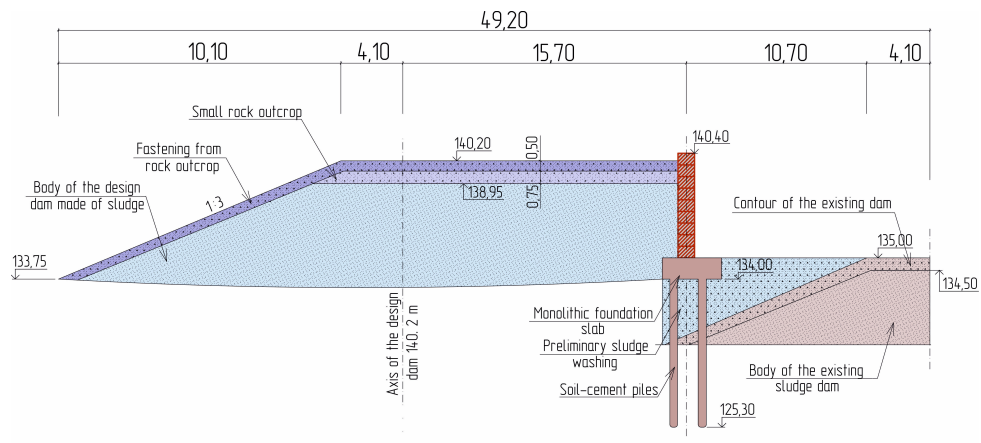
To connect the vertical element consisting of blocks 3 to main slab 1, a block with a straight front face, a pyramidal back face, spike 6 on the lower surface and groove 7 on the upper surface is used. The main components of the vertical element are blocks with a straight front face, a pyramidal back face, groove 7 on the upper surface and spike 6 on the lower surface. The vertical element is completed with a block with a rectilinear front face, a pyramidal back face and spike 6 on the lower surface.

Stability of the retaining wall is ensured by piles 2, spikes 6 and grooves 7 of blocks 3. Blocks 3 can be connected with high-strength mortar 8. The surface in the form of pyramids 4 of blocks 3 in contact with soil 5 significantly reduces the horizontal pressure of soil 5, redistributing it along the height of the retaining wall. The effect increases with active shear of soil 5.

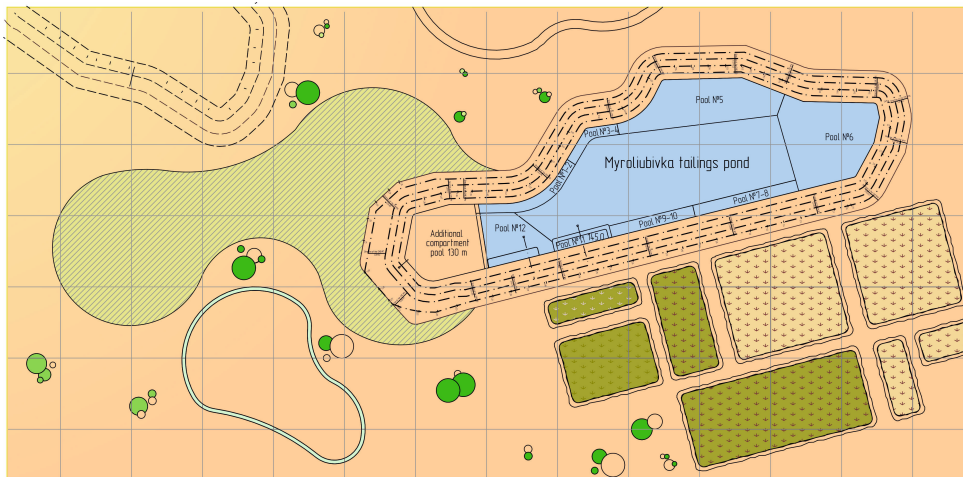
The back surface of the vertical element has two sheets of resilient material 9. Sheets 9 are arranged in two rows and uniformly compact the backfill soil, with the first sheet serving as an anti-friction coating to reduce friction forces. The sheets are made of modern materials that are completely decomposed by microorganisms under aerobic or anaerobic conditions into carbon dioxide, methane, water, biomass and inorganic compounds.

The polymer decomposition period depends on the length and structure of the polymer chain, which in turn makes it possible to select the required polymer composition to perform the tasks set throughout the entire service life of the block retaining wall. Reduction of the polymer chains leads to a loss of mechanical properties (strength, tensile strength, bending strength). Therefore, the sheets of elastic-responsive material 9 are selected as follows: the first sheet from





**Figure 12.** Installation of a prefabricated retaining wall.



**Figure 13.** Flooding area in case of a potential failure.

**4. Conclusions**

Myroliubivka tailings pond is an engineering structure of the first category of responsibility and currently requires new approaches, as well as changes in technology to ensure its stability during long service life.

Available calculation methods based on the theory of linearly deformed media do not fully meet the operating conditions.

Therefore, consideration of the influence of a multilayer nonlinearly deformed massif under external loading allows formulating new principles for determining the horizontal pressure on the retaining wall, namely:

- the mass of sowing between the wall and the shear plane is divided into separate prisms resting within each layer  $h_i$  on the collapse plane;
- the prisms are divided by vertical planes extending from the intersection of the collapse area with the boundaries of the soil layers to the backfill surface (in areas of loaded surface) or to the footwall of the local load;
- part of the distributed load located on any prism is summed with the weight of this prism, i.e. included in the value  $G_i$ ;



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