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Geodesic And Surveying Observation To Ensure The Stability Of The Tailings Dams Of The Copper Processing Plant Cpp (Copper Processing Plant) Almalyk Mining And Metallurgical Combine Based On The Nature Of Geomechanical Processes

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ABSTRACT: The essence of this article is to use the results of surveying instrumental observations of deformation processes occurring in the body of dams and on the surface of slopes of tailings for assessing and predicting their stability, processing and analyzing the results of observations using mathematical statistics methods to develop a proposal to ensure the stability of dams.

The aim of the study is based on monitoring the stability of the tailings at the beneficiation plant of the Almalyk mining and metallurgical plant in the Tashkent region, monitoring current and possible geomechanical processes in its walls and creating a model of soil tension. The article used a complex method of research, mathematical modelling of behaviour of object of research; comparing the theoretical results with the results of actual and surveying observations, the authors developed the dependence of laying the bottom slope of the dam for a preliminary choice of the maximum slope height.

KEY WORDS: tailings, surveying observation, the stability of dams, alluvial dam, bulk dam, profile, slip arc, the dependence of the dam on its height, the graph of depression.

I. INTRODUCTION

In our country and abroad, the construction of special alluvial hydraulic structures — tailings dumps, for storing waste from the mineral enrichment process, is carried out on a large scale. the operation of these structures requires ensuring and observing strict technological control, the failure of which leads to serious accidents and even catastrophes.

The mining and metallurgical industry faces the task of reducing the number of deaths and large-scale disasters to zero. In this regard, rational use of tailings is an integral part of the corporate operating strategy and risk management strategy.

Management of critical controls is defined as an approach to managing unlikely events with large-scale destructive consequences, such as catastrophic accidents at tailings dumps [12].

In the absence of proper management, tailing dumps have primarily a devastating impact on the environment and can threaten health and safety, since pollution from waste water and dust emissions is potentially toxic to humans, animals and plants, and second, unscheduled economic costs. This damage is multiplied many times in the case of physical damage to the tailings storage facility. Flooding with waste from tailings dumps and mountain dumps can cause severe environmental pollution and even lead to loss of life.

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The adopted Law of the Republic of Uzbekistan "on the safety of hydraulic structures" provides for: ensuring control (monitoring) of the state of a hydraulic structure, natural and man-made impacts on it; ensuring the development and timely clarification of safety criteria for a hydraulic structure; developing systems for monitoring the state of a hydraulic structure; ensuring regular inspections of a hydraulic structure; creating material reserves intended to eliminate an accident of a hydraulic structure [2].

The stability of tailings dams is determined by a complex of engineering-geological, hydrogeological and technogenic factors, of which the following have the greatest influence: physical and mechanical characteristics of soils and tailings; technology of construction and operation of the structure; the nature of the base; hydrodynamic, hydrostatic, seismic and dynamic forces acting on the structure; technology of construction and operation of the dam. [12].

The calculations should use methods that meet the equilibrium conditions of the collapse prism and its elements in the limit state and take into account the stress state of the structure and its base. When applied to specific geological conditions and dam design, simplified calculation methods that have been proven in practice can be used with appropriate justification [1].

Therefore, when calculating the stability of dam slopes, the developed methods for calculating and evaluating the stability of quarry slopes and dumps can be successfully used, which take into account the complex engineering-geological, hydrogeological and technological conditions of structures [1].

In our conditions, the object of research is the dams of tailings dumps of AMMC processing plants, the deformation processes occurring in the body of dams and on the surface of the slopes of the CPP tailings dumps.

Study of the state of the OHX dam

The tailings storage facility of the United tailings farm is formed by blocking a lowered section of the area with a pioneer dam and then increasing it by alluvial means. The main parameters of the dam are shown in table. 1.

Table 1

Parameter	Value
Area, m2	$20\ 10^6$
Terrain marks, m	420- 520
The length of the separation dam, m	550
Project fill mark, m	510

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The intensity of growth with a circular alluvium, m/year (The mark of 510 m. m. b. reached by 2028)	1.2-1.5
Wind load (up to 25 m /s - 7 days / year), kg / cm2	38
Snow load, kg/m	50
Freezing depth, m	0.8

The early sites of the Joint Tailings Pond were geotechnical studies by specialized organizations, such as PNIIS (Moscow, 1970), SREDAZNIPROTSVETMET (1977), MECHANOBRINGERING, ONIL mechanics and sustainability of tailings St. Petersburg State Technical University (1992).

According to Mechanobr [4], the structure of the base of the tailings storage site is shown in table 2, the properties of the dam body and the alluvial parameters are shown in table 3 and 4.

Table 2
The coverage areas of the tailings

Breed	**Power, m**	**Humidity, %**	**In water saturation**			
			Angle of internal friction, ^{0}	**Traction force, kg/sm^2**	**Deformation modulus, kg/sm^2**	**Filtration rate, m/day**
Loess-like loams	3-43	4.5-17.3	23-26	015-0.225	89-465	0.11-0.43
Dresano-gravel.soil	2-5					
Gravel	until 15 m					3-27

Table 3
Characteristics of dam body rocks [1]

Breed 2	**ρ_S, g/sm^3**	**ρ_d, g/sm^3**	***e***	**k_ϕ, sm/day**	**φ°**	**c, kg/sm^2**	**Occurrence**
The Sands of the middle	2.73-2.81	1.38-1.68	0.78-0.98	0.002-0.001	30	0	Top of the cut
Small Sands	2.59-2.8	1.34-1.54	0.79-0.95	0.008-0.0004	31.5	0	Under small
The Sands are thin	2.7-2.8	1.42-1.72	0.6-0.97	0.004	30	0.04	The bottom of the section
Loam LV	2.69-2.76	1.27-1.32	1.07-1.15		26[1]	0	Outside tailings

[1]-*small part* of the tailings dam beach adjacent to the outer slope of the alluvial dam was studied. There is no information about the composition and physical and mechanical properties of the soils of the *soaked and sunken* base. After *soaking*, loam has the following properties : broken structure $\varphi=26^0$, c=0. Unbroken $\varphi=27.75^0$.

[2]- symbols accepted in the table.

ρ_S - density of the mineral part.

$\boldsymbol{\rho_d}$ - is the dry density of the soil.

e - porosity coefficient.

$\mathbf{k_\phi}$ - filtration coefficient.

φ - is the angle of internal friction.

c - clutch.

Table 4
Dam alluvial parameters [1]

Parameter	**Value**	**Etc**
According to the project - the consumption of pulp 2 per alluvium, m3 / hour	8274/2068	Tailings of the copper-processing plant/ Tailings of the lead-processing plant
Height, m	3-5	
Width along the ridge, m	10.5	
Heating the bottom slope with a bulldozer	1:5 - 5.9	Dams of collapse
The step of placing the slurry lines along the length of the dam ,	20/10	Tailings of the copper-

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m		processing plant/ Tailings of the lead-processing plant

[1]- the position of the depression curve in the alluvial structure is regularly determined by measuring the water level in piezometers installed according to the project on the pioneer dam and the berms of the alluvial bottom slope.
[2]-the flow Rate of the pulp entering the CPP 2 tailings storage facility increased to 15,000 m^3 / hour by 2000.

METHODS

Stability calculation (table.5) it was produced according to the *Gruntus* program (development of St. Petersburg). The method of the *circular cylindrical sliding surface* and the K.Tertsagi formula are used. The seismic force was taken into account using the method of R.R. Chugayev - turning the structure by the angle corresponding to the coefficient of seismicity θ.

For each calculated mark, the following are considered 4 variants of the *pond positions*: (and depression curves are not given) L_{PP}=0, 200, 300, 500 m. the Calculations are made taking into account the seismicity of 8 ($\theta=4^0 20'$) and 9 ($\theta=8^0 30'$) points.

Table 5
Results for seismics of 8 points [1]

Factory	Crest marks, m	Higher, m	Class of construction and standard safety factors by type[1] of foundation[2]				Distance from the ridge dams to the water edge, m			
			Type B		Type V		0	200	300	500
Copper processing plant	510	75	2	1.14	1	1.18	0.96	1.17	1.21	1.24
	490	55	2	1.14	1	1.18	1.05	1.3	1.33	1.34
	470	35	2	1.14	2	1.14	1.39	1.54	1.59	1.62
Lead processing plant	510	53	2	1.14	1	1.18	0.97	1.35	-	-
	486	29	2	1.14	2	1.14	1.0	1.42	-	-

[1]- safety factors for a special combination of loads according to Building regulations 2.06.05-84.
[2]- according to Building regulations 2.06.01-86: the Base of type B-sandy, coarse, clay soils in a solid and semi- solid state. Base type B-clay water -saturated soils in a plastic state.

Based on the results of the stability calculation, conclusions are made. On absolute mark 490 and 510 m for the distance from the ridge to the water edge of the performed: L≥200m, while the CPP dam is stable only up to absolute mark 476 m, which reached in 2012.

According to the **Hydroproject** [5]:
- Class of enclosing structures 1.
-Most dangerous section: PC 181. (corresponds to 19 profile)
- Estimated seismicity of the tailing dump site is 8 points.
- Category of the base soil for seismicity-3.
-The relative width of the compartment R/b = 200
- Relative center of gravity of the slope = 0.4000

Calculations were performed for physical and mechanical and deformation characteristics of the soil of the embankment and the base (see table.6), determined by the results of research (report no. 1610-T1).

Table 6
Design characteristics of the embankment and Foundation soils on PC 181

Layer of soil		Vs, m/s	Deformation properties		Volume weight, t/m^3		Strength properties	
№	Title		E, t/m^2	ν	Natural	Saturated	Angle of internal friction tgφ	Traction force C, t/m^2
1,3	Loams bases		600	0.38	1.57	1.98	0.4	1.5
2	Sandy loam		600	0.38	1.78	1.99	0.4	1.5

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	bases							
4	Body sand dams	290	2000	0.3	1.82	1.85	0.6	0

The analysis of table 4,5,6 shows that the study of soil strength is insufficient: only loams have been studied at the base of the dam, and for alluvial Sands zero adhesion is accepted, which contradicts the presence in real profiles of slopes whose steepness exceeds the internal friction angle of alluvial Sands (for example. rice. 3, points 8-9). Studies of TSTU [7] show that with such data, the final height of the dam is reduced by 3 m from the design height when evaluated using the method of K.Tertsagi. To reduce the conditionality of assessing the stability of the dam in this work, it is performed not on the average "flat" profile, but on the real profile by the method of K.Tertsagi for the action of a special combination of loads-taking into account seismicity.

Checking the stability of the initial slope (m=5, H=75 m)

II. RESULTS

The calculation of slope stability is done according to the program [10] that implements calculations of the stability of a soil slope based on the seismic forces according to Building regulations 2-A. 12-62 and using the 3 discretization methods the shear: G. Cray (the method is precise and recommended interdepartmental Commission of state construction committee), K.Tertsagi (for slopes with m>2,5 leads to an underestimation of k_{min} (k-stability factor, min–minimum value), R.Chugayev according to Building regulations [9] a criterion for the stability of the dam is the value of the stability ratio, defined by expression:

$$k_s = \frac{R}{F} \geq \frac{\gamma_n \gamma_{fc}}{\gamma_c}$$

where: R - is the calculated value of the generalized *load-bearing capacity* of the "structure-base" system;

F - is the calculated value of the generalized *force effect*;

(γ_c, γ_n, γ_{fc}) - reliability coefficients, respectively, for: *calculation* method, *class* of construction, *combination* of loads, defined in the same place: γ_n= 1.25(1st class of construction), γ_{fc}= 1.0(main combination of loads) , γ_{fc}= 0.9(special combination of loads) , γ_c= 0.95 (simplified method).

Therefore, the *standard value* of the stability coefficient for the main and special combination of loads, respectively, is determined from:

$$\frac{\gamma_n \gamma_{fc}}{\gamma_c} = \frac{1.25 \cdot 1.0}{0.95} = 1.316. \qquad \frac{\gamma_n \gamma_{fc}}{\gamma_c} = \frac{1.25 \cdot 0.9}{0.95} = 1.184.$$

Characteristic points of slope profiles, depression curves, and soils are taken from the drawings.

In the drawings defines two types of soils: alluvial sands and loams of the base table 9. The primary dam is assigned to the base.

Table 9
Characteristics of soil:

Item №	G_{dry}, t/m^3	$G_{saturated}$, t/m^3	ρ °	C, t/m^3
1	1.82	1.85	30.96	0.00
2	1.57	1.98	21.80	1.50

The layout of the profiles is shown in fig. 1, and the actual structure of the profiles on 18.12.2019 is shown in fig. 2 and 3 [13] and in table. 10-15.

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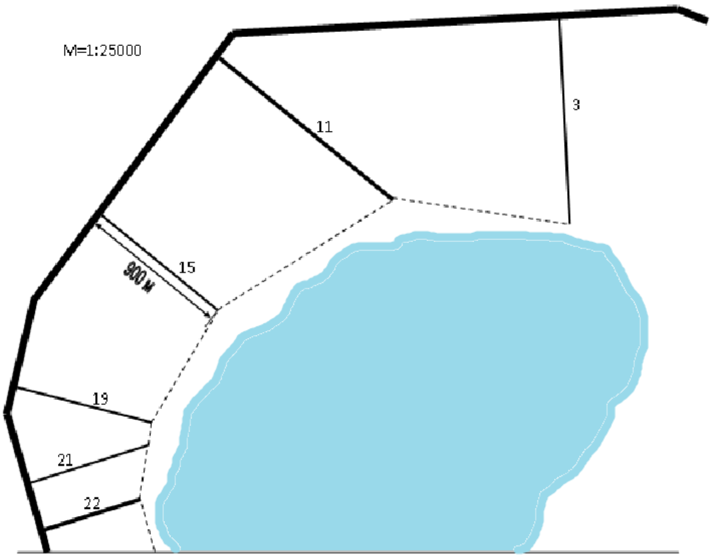

Figure 1. The layout of the profiles for CPP 18.19.2019 (plan view)

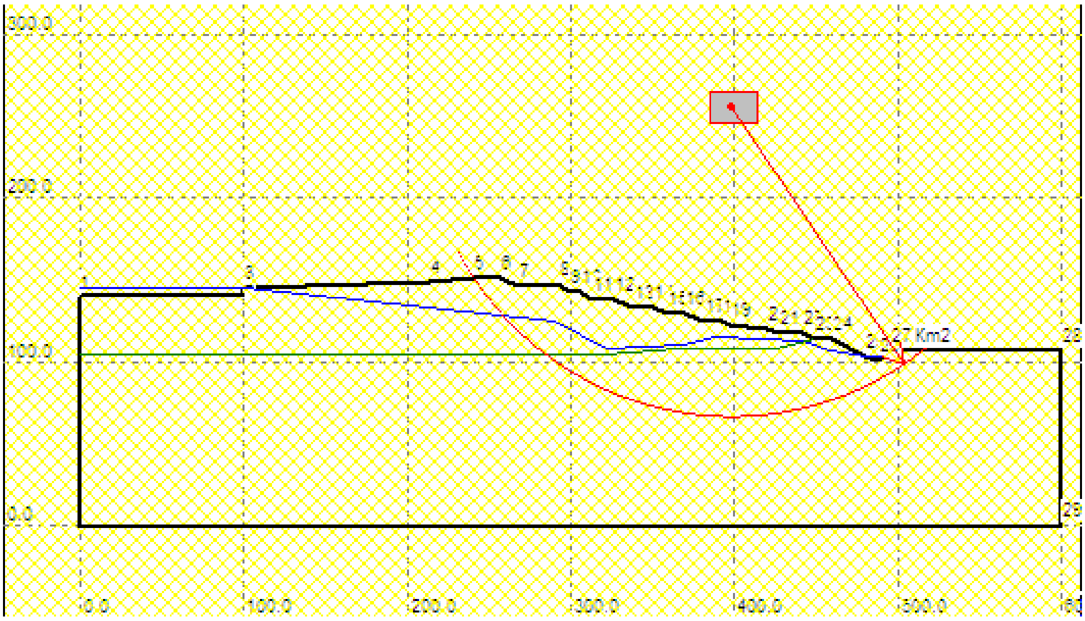

Figure 2. The estimated driving profile 11 of Tertsagi

Table 10

Coordinates of profile slope points 11:

Item №	X, [m]	Y, [m]	Item №	X, [m]	Y, [m]
1	0.00	140.00	16	369.80	129.00
2	99.00	140.00	17	381.30	125.20
3	100.00	145.00	18	392.50	125.20
4	213.50	148.60	19	397.60	122.40
5	240.00	151.60	20	420.00	120.40
6	257.00	151.60	21	427.70	117.50
7	267.00	146.00	22	442.00	117.20
8	293.00	147.00	23	449.00	113.40
9	299.00	142.60	24	460.00	113.40

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10	306.00	142.60	25	480.50	102.80
11	313.00	137.80	26	488.00	100.60
12	326.00	137.80	27	495.00	106.40
13	338.00	133.00	28	600.00	106.40
14	350.00	133.00	29	600.00	0.00
15	358.30	129.00	30	0.00	0.00

Table 11
Coordinates of points of the profile depression curve 11

Item №	X, [m]	Y, [m]	Item №	X, [m]	Y, [m]
1	0.00	145.00	6	388.50	115.00
2	100.50	145.00	7	441.00	112.60
3	290.50	124.20	8	458.00	107.00
4	321.50	108.00	9	480.50	102.80
5	369.00	110.40	10	490.70	102.80

Table 12
Coordinates of soil boundary points in profile 11

Item №	X, [m]	Y, [m]	Item №	X, [m]	Y, [m]
1	0.00	104.40	5	366.00	108.00
2	266.80	104.40	6	421.00	108.00
3	321.00	104.80	7	426.00	107.80
4	336.50	106.00	8	449.00	113.40

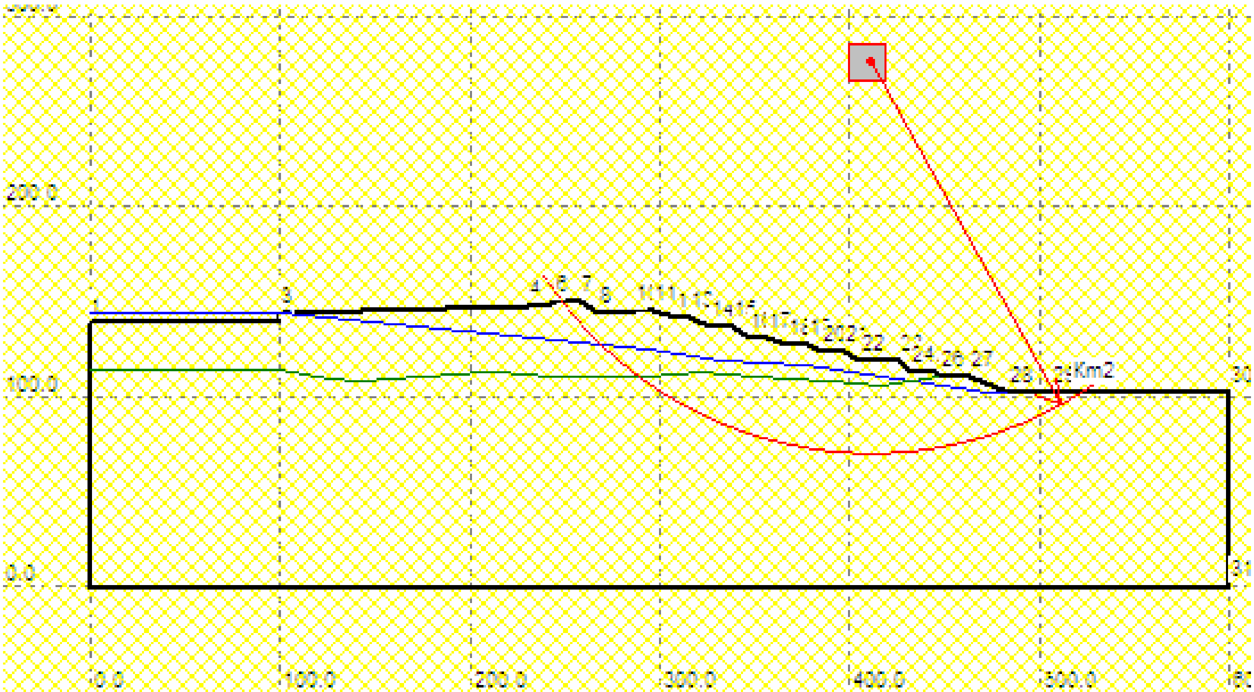

Figure 3. Calculation scheme of profile 22 by Tertsagi

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Table 13
Coordinates of profile slope points 22

Item №	X, [m]	Y, [m]	Item №	X, [m]	Y, [m]	Item №	X, [m]	Y, [m]
1	0.00	139.00	12	308.00	141.40	23	425.50	118.60
2	99.00	139.00	13	316.00	141.60	24	432.50	113.20
3	100.00	143.60	14	326.50	137.00	25	445.50	113.20
4	230.50	147.60	15	337.80	137.00	26	448.00	110.40
5	242.50	148.40	16	346.30	131.20	27	463.00	110.40
6	245.00	149.80	17	356.50	131.20	28	484.00	101.80
7	257.50	149.80	18	366.60	127.20	29	506.50	101.50
8	268.00	144.00	19	378.00	127.20	30	600.00	101.50
9	285.00	144.40	20	385.50	123.60	31	600.00	0.00
10	287.00	145.20	21	397.00	123.60	32	0.00	0.00
11	296.00	145.20	22	405.00	118.60			

Table 14
Coordinates of points of the profile depression curve 22

Item №	X, [m]	Y, [m]	Item №	X, [m]	Y, [m]
1	0.00	143.60	5	377.00	116.20
2	100.00	143.60	6	472.50	102.40
3	294.50	125.20	7	484.00	101.80
4	332.50	119.00	8	0.00	0.00

Table 15
Coordinates of soil boundary points in profile 22

Item №	X, [m]	Y, [m]	Item №	X, [m]	Y, [m]
1	0.00	113.80	13	245.00	109.80
2	100.00	113.80	14	251.00	109.80
3	126.50	109.40	15	260.00	110.40
4	141.50	108.40	16	275.00	110.40
5	145.00	108.20	17	294.00	110.00
6	149.00	108.20	18	322.50	112.40
7	153.00	108.60	19	333.00	112.00
8	156.50	109.60	20	367.00	109.60
9	176.00	110.00	21	390.00	107.60
10	207.00	112.20	22	416.00	105.00
11	216.00	112.40	23	448.00	110.40
12	227.00	111.80	24	0.00	0.00

The stability of the profile was evaluated by iterating through the values of the following parameters: coordinates of the center area (X, Y), radiuses' of the sliding arcs (R), and the number of split points for (X, Y, R). At the same time, even a significant change in the named parameters gave only a slight change in the coefficient of stability margin K. the parameters corresponding to the minimum k_{min} were accepted and then refined. In table 16-19 shows the parameters of the final step.

Table 16
Profile center area 11

Name	X, [m]	Y, [m]	R, [m]
Min. values	385.00	245.00	170.00

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Max. values	415.00	265.00	290.00
Number of points	17	15	45

Table 17
Results of the calculation using K.Tertsagi profile 11 method

Item №	K_{min}	R_{min}, [m]	X_{min}, [m]	Y_{min}, [m]
1	1.4041509	170.00	398.13	245.00
45	99.0000000	290.00	385.00	245.00
Min.	1.3847386	189.09	398.13	255.00

Table 18
Area of profile centers 22

Name	X, [m]	Y, [m]	R, [m]
Min. values	400.00	265.00	205.00
Max. values	420.00	285.00	235.00
Number of points	15	15	30

Table 19
Results of calculation Using the K. Tertsagi method of profile 22

Item №	K_{min}	R_{min}, [m]	X_{min}, [m]	Y_{min}, [m]
1	1.2472837	205.00	410.00	273.57
30	1.3129538	235.00	414.29	285.00
Min.	1.2465735	206.03	411.43	276.43

In table 20 the comparison of the standard value of K_N (K–the coefficient of stability, the normal value) and calculated for profiles is given.

At the same time, the stability of both profiles is ensured , but for profile 22 it is significantly reduced, since this profile has a less favorable depression graph for stability (fig 2 and 3). In the pressure part of the sliding arc (approx. up to a vertical of 400 m) the depression line in profile 22 is higher than in profile 11 and means more heavy-wet mass. This fact is all the more interesting because the steepness of the full profile 22 is lower than that of the profile 11, table 21.

Table 20
The analysis of stability of profiles

K_N	K_{11}	K_{22}
1.184	1.385	1.247

Table 21
The calculation of the slope (backwards m) at the points of the profile

<table>
<tr><td colspan="5">Profile 11</td><td colspan="5">Profile 22</td><td colspan="5">Profile 22 locally</td></tr>
<tr><td>№</td><td>X</td><td>Y</td><td>m</td><td>1/m</td><td>№</td><td>X</td><td>Y</td><td>m</td><td>1/m</td><td>№</td><td>X</td><td>Y</td><td>m</td><td>1/m</td></tr>
<tr><td>6</td><td>257</td><td>151.6</td><td rowspan="2">4.58</td><td rowspan="2">0.218</td><td>7</td><td>257.5</td><td>149.8</td><td rowspan="2">4.72</td><td rowspan="2">0.212</td><td>11</td><td>296</td><td>145.2</td><td rowspan="2">4.33</td><td rowspan="2">0.231</td></tr>
<tr><td>25</td><td>480.5</td><td>102.8</td><td>28</td><td>484</td><td>101.8</td><td>28</td><td>484</td><td>101.8</td></tr>
</table>

The structure of profile 22 is such that its local area (fig.4, table 22,23) has even less stability than shown in the table 20 (K_{22L}=1.222). This is due to the greater steepness of the local zone (0.231) than the entire profile 22 (0.212). Note that the K_{22L} value is only 3,2% higher than the standard value.

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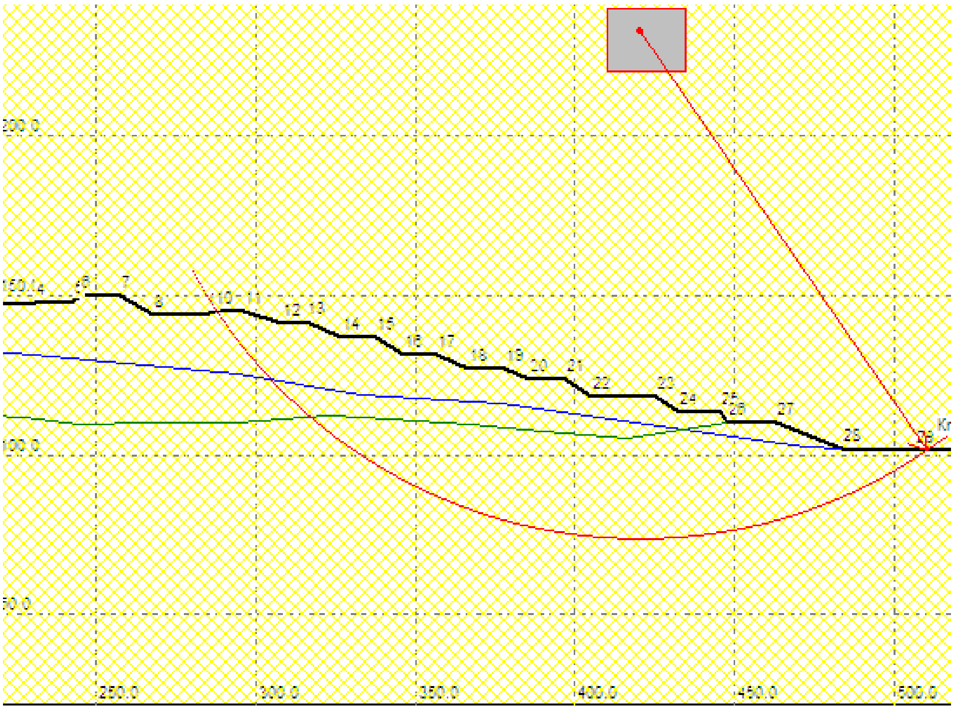

Figure.4. Local area of the profile 22 of increased steepness

Table 22
Area of profile centers 22L

Name	X, [m]	Y, [m]	R, [m]
Min. values	410.00	220.00	130.00
Max. values	435.00	240.00	200.00
Number of points	15	15	25

Table 23
The results of the calculation by the method of K.Tertsagi profile 22L

Item №	K_{min}	R_{min}, [m]	Xmin, [m]	Ymin, [m]
1	1.3273093	130.00	433.21	220.00
25	1.3219689	200.00	411.79	240.00
Min.	1.2221196	159.17	420.71	232.86

In table 24 some important profile parameters have been defined

Table 24
Important profile parameters

Parameter	Value
The height of the profile 11, m	48.8
Profile height 22, m	48.0
Height of the local area of the profile 22L, m	43.4
Slope coefficient m of the profile 11, m	4.58
Slope coefficient m of the profile 22, m	4.72
Slope position coefficient m of the profile 22L, m	4.33
Laying from the upper edge to the water edge of the profile 11, m	157.0
Laying from the upper edge to the water edge of the profile 22, m	157.5
Laying from the top edge to the border of the pressure zone of the profile 11, m	141.1

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Application from the top edge to the border of the pressure zone of the profile 22, m	153.9
Laying from the local upper edge to the boundary of the pressure zone of the profile 22L, m	124.7

III. CONCLUSIONS

- A study of the stability of two profiles of the OHX dam with a height of 68-69 m as of 18.12.2019 was performed. The dam is currently stable.

-It was found that the stability of the profile depends more on reducing the level of depression in the pressure part of the slide arc than on reducing the slope of the dam slope. In this regard, to improve the stability of the dam, we can recommend the creation of filter water outlets in the pressure zone of the slip arc inside the body of the dam.

- It is not recommended to fall off, in which there are local zones of high steepness.

- The conditionality of the strength characteristics of the Foundation and dam soils is largely preserved to this day.

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