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Evaluation of the design parameters of overburden dump construction from an open pit mine in Bulgaria

Evaluation des projets de paramètres d'un terril d'une mine à ciel ouvert en Bulgarie

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ABSTRACT

The overburden disposal area for the Asarel Mine, called "West Dump", is situated at the edge of the pond of "Lulakovitza" tailings dam. The design height of the dump is 320m and the tailings materials will reach to 100-120m of the dump height.

Overburden materials from open pit "Asarel" are very heterogeneous, containing 40 – 60% clay minerals and the rock materials from mine excavation are highly weathered. The overburden dumping is performed to vertical heights up to 100m, through use of a crusher-conveyor-stacker system, with the resulting dimensions of the deposited materials being less than 0.30m.

The method of overburden disposal makes it impossible to select the hard material to guaranty the stability of dangerous zones of the dump. From a technological and financial point of view, it is difficult to take undisturbed samples for determination of real physical and mechanical properties of deposit materials.

Taking into account the specific characteristics of the deposit materials, slope stability evaluation is performed on the basis of physical and mechanical characteristics only of the coarse and fine-grained materials.

Laboratory and in-situ investigations are performed to determinate the basic physical, deformation and strength properties of the deposited materials. The nonlinear relationships of the unit weight, secant modulus and shear modulus affected by the dump height is presented.

To arrive at reliable design characteristics for construction of the overburden dump, a comprehensive stress-strain analysis of the dump is performed by means comparing the in-situ measured settlement and computed settlement by using the computer program "PLAXIS".

The results obtained are used for predicting the stress-strain behavior and slope stability analysis of the overburden disposal dump.

RÉSUMÉ

Le teril de la mine à ciel ouvert "Assarel", appelé "Terril d'Ouest" est situé dans la cuvette du bassin a déchets de lavage de "Lulacovitza". Le projet de hauteur de terril est de 320 m, le bassin à déchets de lavage couvrant environ 100 à 320 m, le bassin a déchets de lavage couvrant environ 100 à 120m de la hauteur du terril. Le matériau de remblai de la mine à ciel ouvert "Assarel"est assez hétérogène, contenant de 40 à 60 % d'argile, les matériaux de roche des déblais minieres s'altérant de façon très forte. Le remblayage est effectué à une hauteur de 100 m en utilisant un systeme de bandes transporteurs, ce qui mène à une dimension maximale du matériau de remblai de 0,30 m. Cette méthode de remblage ne permet pas de choisir un matériau meilleur pour guarantir la solidité des zones dangereuses dans le terril. Pour des raisons technologiques et financièrs, il est difficile de prendre des èchntillons non-perturbés pour déterminer les indices physiques et méchaniques du matériau de remblai.

En prenant en considération les caractéristiques spécifiques du matériau de remblai, la stabilité des pentes n'est déterminée que sur la base des caractéristiques physiques et méchaniques des petite fractions.

Des études de laboratoire et in situ sont effectuées pour déterminer les caractéristiques essentielles physiques, de déformation et de solidité du matériau. Sont présentées les relations non-linéaires du poids unitaire, le module sécant et le module de découpage selon la hauteur du remblai.

Pour obtenir les projets de caractéristiques pour la construction du terril, ont été faites des evaluations comparatives de l'état de tension et de déformation du remblai pour une comparaison des affaissements mesurés et calculés en utilisant le programme "PLAXIS"
Les resultats obtenus sont utilizés pour établir un pronostic concernant l'état de tension et de déformation et la solidité de la pente du terril.

1 INTRODUCTION

The overburden disposal area for the "Asarel" mine, called "West Dump", is situated at the edge of "Lulakovitza" tailings pond. The design height of the dump is 320 m and the tailings materials will reach to 100 -120 m of the dump height.

Overburden materials from the open pit "Asarel" are very heterogeneous, containing 40-60 % clay materials and the rock materials from mine excavation are highly weathered. The overburden dumping is performed to vertical heights up to 100 m, through use of a crusher-conveyer –stacker system, with the resulting dimensions of the deposited materials being lees than 0.30 m.

The method of overburden disposal makes it impossible to select the hard material to guaranty the stability of dangerous zones of the dump.

From a technological point of view, it is difficult to take undisturbed samples for determination of real physical and mechanical properties of deposit materials.

Furthermore, there is no possible way to overburden the downstream slope with a selected material of the needed high quality.

In this case, if the calculations are made with higher properties, the slope will collapse.

Penetration research of the dump are not possible because of the presence of rocky pieces. Taking disturbed sample of the dump surface in large excavations will not provide a reliable assessment of the dump soil distributions because some samples there could contain more rocky pieces and in other – less.

Taking undisturbed samples with borehole is also not representative because the dump condition is changed in the course of taking the sample.

Taking into account the specific characteristics of the deposit materials, slope stability evaluation is performed on the basis of physical and mechanical characteristics only of the coarse and fine-grained materials.

Sufficient number of samples for detailed examination can be taken from this fine – grained material.

No matter how the material weathers, it will reach the properties of fine – grained material.

The dump is constructed in three stages: first stage – up to level 935; second stage: up to level 1000; third stage: up to level 1060.

Up to now, level 935 is being constructed. Part of it is overburdened with weak materials.

In the first several days after the overburdening of the dump, the material in the top of it slumped and the bottom of the slope bulged several meters.

The positioning of "West Dump" in the reservoir of the tailing pond represents a enormous possible threat for the safety of the tailings dam. If part of the dump slope collapses in the pond, the water and slams in the pond could over flood the dam crest. The water and slimes will erode 120 meters of the dam's height.

Failure of the "West Dump" downstream slope must not be allowed to happen because the water of the pond may overflow the tailings dam crest and destroy the whole dam.

This could cause disastrous consequences for the whole region, potentially resulting in significant material and human losses

Besides, this region is the one with the highest seismic activity in Bulgaria.

A certain decrease in the physical and mechanical characteristics of the disposing materials results in increasing the factor of stability. This is so because the real characteristics of the materials are higher.

That is why, the new project for defining dump slope stability uses a conservative approach in order to increase the factor of safety.

Table 1.

Characteristics	Signature	Dimensions	Average values
Grain size distribution			
>200mm	Cobbles	%	20
200,0 – 20, 0	Gravel coarse	%	61
20,0 – 5,0 mm	Gravel-medium	%	8
5,0 – 2,0 mm	Gravel-fine	%	3
2,0 – 0,1 mm	sand	%	5
< 0,1 mm	silt	%	3
Uniformly coefficient	$U = d_{60}/d_{10}$		70
Specific gravity	ρ_s	g/cm^3	2,73
Dry density in loosest state	$\rho_{d,min}$	g/cm^3	1,37
Dry density in densest state	$\rho_{d,max}$	g/cm^3	1,60
Water content	w_n	%	6,5
Compression modulus (for load)			
P = 0,2 MPa	M	MPa	4,6
P = 0,4 MPa	M	MPa	8,2
P = 0,6 MPa	M	MPa	20,7
Angle in internal friction			
In natural moisture	φ	degree	43
Saturated	φ	degree	38
Cohesion			
In natural moisture	c	MPa	0,008
Saturated	c	MPa	0,020

2 BASIC GEOTECHNICAL CHARACTERISTICS OF THE EMBANKMENT MATERIALS

For determination of the basic physical and mechanical characteristics of the dump embankment materials, laboratory and in situ tests are performed. The identification characteristics, the shear strength and compression tests are performed in laboratory according to standard methods. The in situ tests are performed over experimentally embankment performed on the site.

The basic results from laboratory tests are given in table 1.

A prognostic variations of the dry unit weight (γ_d) and natural unit weight (γ_n) with depth of the embankment are given on figure 1.

The experimental embankment have been performed in two variants – with 100cm and 50cm compacted layers. The compacted zones, 6,0m wide, were compacted with different passes (4, 6 and 8 passes of a vibrating compactor machine. The results of the in situ measurements gave relatively high values of the dry density in compacted state ($\rho_{d,max}$ >2,10 g/cm^3), reached at natural water content w_n= 4 - 5 %).

The in situ plate loading tests were performed for determination of the modulus of linear strain. A comparison of the com pression and in situ deformation modulus show that in situ modulus is approximately two times more than compression.

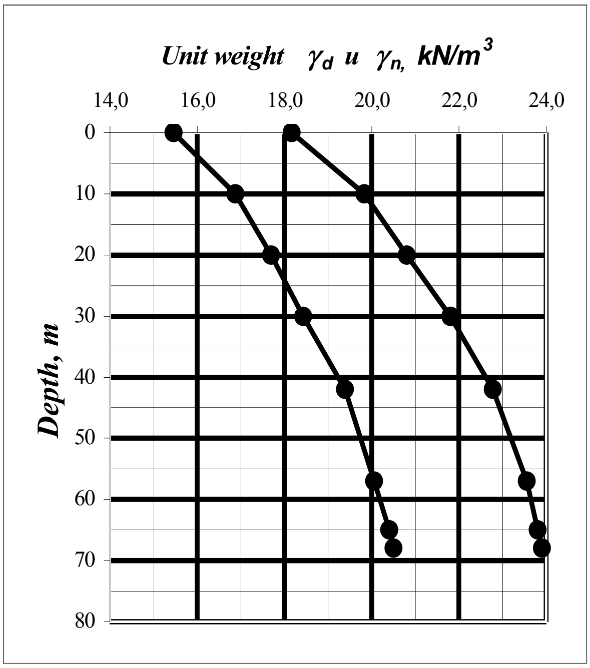

Figure 1. Variation of the unit weight with embankment depth

3 EVALUATION OF GEOTECHNICAL PROPERTIES USED FOR DETERMINATION OF STRESS – STRAIN BEHAVIOR OF THE DUMP.

If the slope stability is defined through the indicators of fine – grained material, it will be the lowest possible stability.

In reality, the dump has higher indicators and higher stability overall.

Material in the dump up to level 935 is divided in zones according to its physical and mechanical properties into zones at 10 meters from each other in depth. These zones are parallel to the dam contour in the horizontal part and the slopes.

The settlement of the dump at level 935 is measured for this profile – at – place. This settlement is defined and depends on the real parameters of the dump.

That is why, the real parameters of the slope in the dump can be defined through calculation of the stress – strain behavior of the dump for real settlement.

Parameters change, having in mind non linear characteristics of fine – grained material.

These calculations are made with PLAXIS program by changing dump properties until calculated and real settlement at level 935 in the examined profile become equal.

These parameters are considered as initial. Comparative calculations for defining real parameters of dump in the highest profile examined were made.

The calculation method Mohr Coulomb was considered for usage.

4 BASIC RESULTS OF CALCULATIONS OF STRESSES AND SETTLEMENTS OF DUMP.

The results from the calculation are shown in table 2 and figures 2;3 and 4 for Initial properties and table 3, figures 5;6 and 7 for Corrected properties.
For weak materials the following results were obtained:
At Figure 2 extreme total displacements are 10.43 meters.
At Figure 3 extreme horizontal displacements are 5.50 meters.
At Figure 4 extreme vertical displacements are 8.89 meters.

Table 2. Initial properties

Name	γ kN/m^3	ν	E kN/m^2	C kN/m^2	φ ^{0}
ground	24,3	0,10	1E6	400,0	40,0
1	16,2	0,20	2500	5,0	30,0
2	17,4	0,19	5000	6,0	30,5
3	18,0	0,19	8000	7,0	31,0
4	18,8	0,18	12000	8,0	32,0
5	19,6	0,17	16000	10,0	33,0
6	20,1	0,17	29000	10,0	35,0

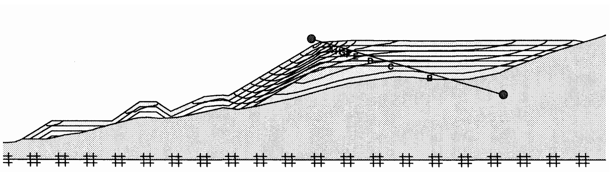

Figure 2 Total displacements. Initial properties

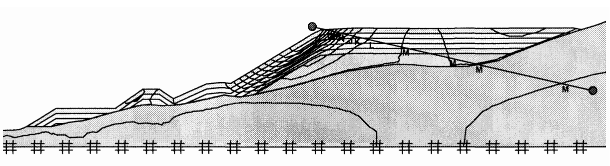

Figure 3. Horizontal displacements Initial properties

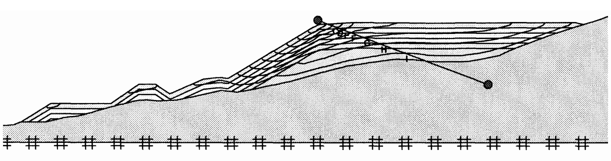

Figure 4. Vertical displacements. Initial properties

For the corrected properties the following results were obtained:
At Figure 5 extreme total displacements are 4.42 meters.
At Figure 6 extreme horizontal displacements are 4.58 meters.
At Figure 7 extreme vertical displacements are 4.03 meters.

These care similar to the settlements which were taken at place and which differ from the calculation with about 3,5%.

Calculation results reveal that real (as dumped) physical and mechanical properties of deposit materials are higher than those of the fine - grained materials according to which the dump stability is defined. Therefore, as stated in sections 2 & 3 above, the engineering project slopes build in a conservative calculation for the slope angles and therefore overall slope stability.

Table 3. Corrected properties

Name	γ kN/m^3	ν	E kN/m^2	C kN/m^2	φ ^{0}
ground	24,3	0,10	1E6	400,0	40,0
1	17,3	0,21	8000	4,0	28,0
2	20,4	0,20	17000	5,0	29,5
3	20,5	0,20	25000	6,0	30,0
4	20,8	0,19	31000	7,0	31,0
5	21,1	0,18	37500	8,5	32,0
6	21,3	0,17	45000	9,0	33,0

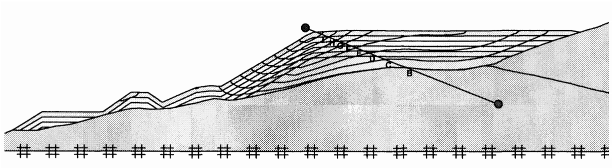

Figure 5. Total displacements. Corrected properties

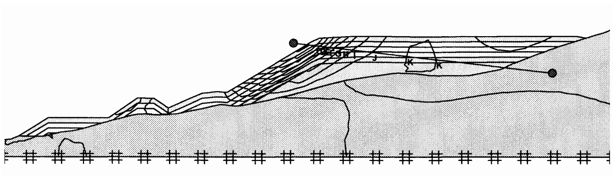

Figure 6. Horizontal displacements. Corrected properties

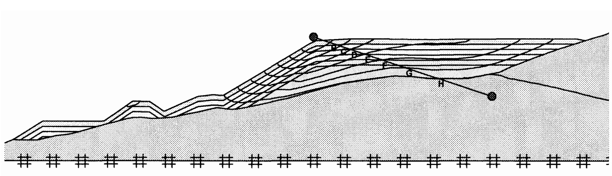

Figure 7. Vertical displacements. Corrected properties

5 CONCLUSIONS

The positioning of " West Dump"in the reservoir of the tailings dam, which will result in the pond flooding 120 meters from the bottom of the dump is not only a serious threat for the security of the dam and the dump, but also an enormous professional challenge of finding the best way for the dump deposition problems to be solved.

Failure of the "West Dump" downstream slope must not be allowed to happen because the water of the pond may overflow the tailings dam crest and destroy the whole dam.

This could potentially result in serious consequences for the whole region, causing possible material and human losses.

Besides, this region is the one with the highest seismic activity in Bulgaria.

That is why, a conservative approach has been applied for defining the slope stability. It assumes a certain decrease in the actual physical and mechanical properties of the disposed waste materials and the calculated slope stability is lower than the actual deposited material slope stability.

This is valid only in general, as, according to the practice, the slopes of the dump are dangerously deformed only when weak materials are overburdened.

When there are limited conditions for taking undisturbed samples from the dump for laboratory examination of the material and limited possibilities of defining the in situ material characteristics it is appropriate the slopes stability to be defined through the properties of fine - grained material.

Defining material properties by calculation and using the least stable material physical and mechanical characteristics, gives the possibility to estimate the dump slopes safety factor which will actually provide a "reserve" safety factor.

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