GEOTECHNICAL RESEARCH OF THE ROCKS FROM THE TAILINGS DUMPS IN THE WEST OF THE JIU VALLEY REGARDING THE STABILITY OF THEIR SLOPES

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Abstract: The extractive industry, through the specific activities it involves, has a significant geotechnical and ecological impact on the environment, with dominance at the local level, near the mining units through the storage of mining residues resulting from the extraction processes. The different parts of the mine: mining premises, mine waste dumps, industrial buildings, social buildings, roads, platforms can have end uses such as: reproductions in the agricultural and forestry circuit, creation of waste deposits, recreational areas, industrial parks, retention basins. The rocks that are stored in the dump are made up of an inhomogeneous material from a petrographic and granulometric point of view. The waste resulting from the preparations is represented by a mixture of clays, shale clays, gritty clays, coal shale, coal fragments. This paper presents the research of the rocks from the tailings dumps in the west part of Jiu Valley.

Keywords: rocks, tailings dumps, contaminants, mining, mineral resources

1. INTRODUCTION

The extractive industry, through the specific activities it involves, has a significant geotechnical and ecological impact on the environment, with dominance at the local level, near the mining units through the storage of mining residues resulting from the extraction processes. This impact has on the surface waters, the modification of the hydrology and the pollution of the ground waters, the elimination of contaminants in the atmosphere, the destruction of the basic land as a result of the direct mining operations by depositing the tailings in the dumps, all of which constitute pressure factors on the environmental components.

The activity of closing the mining objectives and the ecological reconstruction

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of the areas affected by the exploitation works is one of the most complex activities related to the exploitation and valorization of mineral resource reserves.

The different parts of the mine: mining premises, mine waste dumps, industrial buildings, social buildings, roads, platforms can have end uses such as: reproductions in the agricultural and forestry circuit, creation of waste deposits, recreational areas, industrial parks, retention basins.[1]

Dozens of tailings dump from Jiu Valley attack the environment and permanently threaten the houses built near them. Active or inactive, stable or not, dumps are impregnated with water from heavy rains, which tend to slide.

The rocks that are stored in the dump are made up of an inhomogeneous material from a petrographic and granulometric point of view. The waste resulting from the preparations is represented by a mixture of clays, shale clays, gritty clays, coal shale, coal fragments.

The presence of a significant fuel potential in the stored sterile mass justifies the research of the possibilities of recovery, at least partially, of it and its valorization in energy alongside the current production. In some areas of the sterile warehouses, the calorific value exceeds 1500kcal/kg. It is possible to recover an energetic fuel whose calorific value is 2500-3600 kcal/kg.

The re-depositing of the final tailings will raise specific problems due to the even higher content of clay minerals than currently found in the dumps, to which is added the much finer granulation, while the processing will favor the further degradation of the component mineral material. The extraction of combustible components from sterile dumps will require changes to the current geotopometric configurations of the deposits, an opportunity to envisage ecological rehabilitation works, activities that are stimulated by government programs.[2],[3]

Mine tailings dumps occupy an important area in the Jiu Valley, but in addition to the appearance they give to the area and the sources of pollution they generate, they represent a step back on the path of sustainable development. Tailings dumps are located near current and former mining operations and coal preparation plants.

At the level of the Mining Basin, in the western part of the Jiu Valley, a number of 20 dumps are registered. In total, the landfills store a volume of 26,361,091 sterile m^3 and occupy an area of 8,855 ha from the forestry and agricultural circuit. The tailings deposits came from underground mining works in a proportion of 43% in a total area of 113 ha, from day mining works 22% representing 57 ha, from coal preparations 34%, i.e., 88 ha, being generally located in the vicinity mining units and populated areas. Most of the dumps built on an inclined background or those whose geometric parameters are insufficiently substantiated, constitute a potential danger of instability.[4]

2. METHODOLOGY AND RESULTS

Solving the problems regarding the stability of the piled rocks is only possible based on the knowledge of the physical-mechanical characteristics of the piled rocks that characterize the rocks in their natural state and their behavior under mechanical stress.

The studies performed until now to determine the physical-mechanical characteristics of the rocks from the tailings dumps in the Ji Valley mining basin were performed at mining units that showed interest at a certain time in collaboration with different research institutes and the University of Petrosani.

We carried out the laboratory determinations in compliance with the STAS in force and followed: general identification indices; natural state indices; water behavior indicators; mechanical indices. For the identified rocks, specific mechanical determinations were performed both in the natural state and in the saturation state.

Table 1. **Rocks characteristic of tailings dumps from the Jiu Valley mine basin**

No.	Specification	U/M	Percentage
1.	Granulometric composition: - clay (< 0,005mm) - dust (0,05- 0,005mm) - sand (0,05- 2mm) - gravel: ф=2-10mm ф=10-20mm - blocks (over 20mm)	%	 2,4-5,6 5,9-10,2 15,68-25,1 51,66-58,0 - 9,62-14,94
2.	Apparent specific density $\gamma_a x10^4$	N/m^3	2,61-2,70
3.	Volumetric density $\gamma x10^4$	N/m^3	1,95-2,06
4.	Natural humidity	%	12,08-14,31
5.	Porosity	%	31,08-34,64
6.	Pore index	-	0,45-0,52
7.	Saturation coefficient	-	0,72
8.	Coefficient of compressibility E_p 10^{-2}	MPa	1,00-1,94
9.	Modulus of compressibility E_c 10^{-6}	MPa	0,71-1,00
10.	Specific settlement e_c	cm/m	4,30-7,35

In table 1 we presented the granulometry and physical properties of the mixture of heaped rocks from the Jiu Valley mining basin.

The problems that determine the stability of embankments are encountered in road, railway, hydrotechnical constructions, canals, dams, retaining walls, dams, the execution of tunnels, coastal galleries, landfills, civil constructions, the protection of inhabited or cultivated areas with bumpy relief or near streams, rivers, as well as embankments in open pit quarries. These constructions are or become unstable over time. The movements of the rock massif, of the earth's crust, can be actual or potential. For potential movements, the stability study must be designed in such a way as to find the most probable movement and at the same time correspond to a minimum safety. The massif of rock and of the surface of the land can determine movements in the following situations: natural embankments, embankments of trenches executed in massifs of natural rock, embankments made in massifs of clastic rock resulting from landslides or constructions such as dams, dumps, [2]

The presence of movements in rock massifs over large areas cannot be prevented by man by finding a definitive remedy. On the contrary, when the moving rock masses are not too important, the means of intervention that are taken can be effective and will allow stabilization. These means consist of: draining the massif in such a way as to modify or even suppress the percolation forces or the hydraulic pressures in the permeable layers; changing the distribution of unstable masses through embankments, either unloading the driving area or loading the stabilized area; the introduction of stabilizing forces by building works such as grates; using anchors or continuous wall insulation boards; the realization of some plantations on the surface of the unstable masses with the role of evapotranspiration and a decrease in the amount of infiltration water.

An important role is played by the design and analysis of the stability of the embankments based on real data related to the area, the region in which they are to be realized. Designing an embankment means determining its shape and height under conditions of guaranteed stability.

The degree of ensuring the stability of the embankments is expressed mathematically by a "safety coefficient", "stability factor" or "safety factor" (FS) defined as the ratio between the resistance forces and those that determine or produce the instability or between the stress's stabilizers and motor voltages.

For the concept of stability factor "FS" which indicates by its value whether the embankment is stable or not, in the specialized literature there are several definitions depending on the known or imposed quantities.

An exception to this situation is the case where the surface on which the instability phenomenon occurs is predefined by the geological conditions, being made up of several fracture surfaces. The stability factor in such situations with the most probable value is considered to be the one with the lowest value.

To have a stable embankment, (FS) > 1, i.e., there must be a reserve of stability.

The stability factor is taken higher, depending on the degree of indeterminacy of the problem. Stability has a relative character: (i) both from the point of view of time, the stability coefficient having different values for embankments with different definitive or operational durations:

$$(FS) = \left[\frac{(t+b)}{a} \right]^{\frac{1}{n}} \tag{1}$$

Where a and b are coefficients that depend on the resistance properties of the rocks; n is a coefficient depending on the nature of the rock and its behavior when breaking by shearing; t is the length of the embankment. From a spatial point of view, the value of the stability coefficient (FS) varies from 2 - 2.5 at the top of the slope, up to 1-1.3 at its base.

In table 2 the embankment angles are shown depending on the parameters a, b and n, and the stability factor depending on time is shown in table 3.

Rock instability can occur through the appearance and development of fracture surfaces inside the massif, through the development of inelastic deformation zones or due to the creep phenomenon, consequences of the secondary stress state created in the massif with the execution of the slope in it. As a result of the secondary state of tension that appears in the embankments, as soon as they have been executed in the rock massifs, the phenomenon of loss of their stability is expected if the design of their geometric elements was not carried out in the context of this state and all the factors that determine their stability.

Table 2. **Values of coefficients used in determining the long-term stability of embankment**

Structural-textural characterization of soils or rocks, respectively of the massif.	**Embankment angle value θ [degrees]**								
	10º – 30º			**30º – 60º**			**> 60º**		
	a	**b**	**n**	**a**	**b**	**n**	**a**	**b**	**n**
Homogeneous, unaffected by surfaces of minimum resistance or structural weaknesses; stable	1,1	0,9	6,0	1,18	0,91	5,2	1,16	0,95	4,9
Homogeneous, slightly cracked; of medium stability	1,16	0,87	5,5	1,09	0,86	4,8	1,1	0,85	4,7
Homogeneous; cracked; of low to medium stability, i.e. suitable.	1,05	0,83	5,0	1,04	0,81	4,6	1,05	0,8	4,2
Inhomogeneous; consisting of blocks; the distribution of stresses in the massif is uneven.	1,06	0,8	4,5	1,03	0,76	4,2	1,0	0,7	4,0

Table 3. **The stability factor depending on the duration of the embankment**

The stability factor (FS)	**Duration of existence of the embankment T [years]**
1,1 – 1,2	1
1,2 – 1,5	20
1,5 – 2,0	> 20
3	ancient

In this case, the equilibrium of the unstable rock mass considered as a single solid material system that moves without deforming is analyzed.

In real conditions, the rock mass is heterogeneous and therefore the failure surface is often extremely complex, therefore the stability analysis can only be done by dividing the unstable mass into several elements which are then studied individually in the limit equilibrium state.

To carry out the stability analysis, the forces acting on the unstable rock mass must be determined at the same time. These forces are composed of driving forces and stabilizing forces

3. CONCLUSIONS

The systemic approach to slope stability leads to the need to determine the factors that act on the slope considered as a system, as well as to define the state parameters of this system.

The causal factors can be grouped as follows:

- Climatological factors: precipitation, freezing, thawing, temperature, wind, drought.
- Natural mechanical factors: erosion, abrasion, subduction, earthquakes.
- Biotic factors: the presence or absence of vegetation, the nature of the vegetation, the development of microorganisms, etc.
- Anthropogenic factors: earthworks, building installations, excavations, deposits, deforestation, creation of reservoirs, etc.

Other causative factors: currently are or may be considered unknown.

The levels of disturbing factors can be expressed quantitatively only for a part of them, the rest can only be assessed qualitatively. It is also not possible to establish the critical levels of these factors.

The stability study can be carried out:

1) in the short term;

2) in the long term.

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REFERENCES

[1]. **Stanimirescu, (Șoica) A., Egri, A.** *The influence of tailing dumps on the environment from a chemical and pedological point of view at the level of the Berbesti-Alunu basin.* Annals of the University of Petroşani, Mechanical Engineering, 24 (2022), 145-150.

[2]. **Davidescu, G.** *Valea Jiului și șocul viitorului*. Editura Focus, Petroșani, 2006.

[3]. **Dumitrescu, I**., *Poluarea mediului*, Editura Focus, Petroşani, 200210

[4]. **Dumitrescu, I**. *Impactul activităţilor antropice asupra mediului, note de curs*, Petroşani, 2006

[5]. **Munteanu, A.M.** *Mișcarea ecologista și jurnalist de mediu.* Editura Universitară, București, 2015.

[6]. **Marinescu, D., Petre, M.-C**. *Tratat de dreptul mediului*. Editura Universitară, București, 2014.

[7]. **Irimie, S.I., Radu, S.M., Petrilean, D.C., Andras, A.** *Reducing the environmental impact of a gas operated cogeneration installation*. In Matec Web of Conferences (2017, Vol. 121, p. 10005). EDP Sciences.