SCIENTIFIC AND TECHNICAL UNION OF MINING, GEOLOGY AND METALLURGY

FEDERATION OF THE SCIENTIFIC ENGINEERING UNIONS IN BULGARIA

PROCEEDINGS OF THE VII INTERNATIONAL GEOMECHANICS CONFERENCE

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A. Physical and mechanical rock properties. Methods and means of identification.

B. Stressed and deformed state of the rock mass. Technological solutions and systems for management of the rock pressure.

C. Stability of flanks and slopes.

D. Geodynamic impacts on underground and surface excavation equipment. Geomechanical securing of rock falls and landslides.

E. Mine-surveying methods and computer systems for monitoring and management.

F. Ecology and environment protection.

REHABILITATION OF THE LANDSLIDE – MONITORING, MEASURES AND PROCEDURES FOR FAST REHABILITATION

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ABSTRACT
This paper concerns the geotechnical slope stability of the excavated blocks in open pit "Central ore body" in the north and northwest. In fact, in this part is already manifested geotechnical instability expressed by landslides and cracks with exceptional geotechnical deformations. This is a sure sign that the process of slope destabilizing of the northern side of the open pit is continuing and it requires serious treatment to overcome or minimize the possible damages and dangers.
With the monitoring of the situation on the terrain, full deformation monitoring, groundwater level, directions of slipping and deformation it was made a geotechnical analysis on excavated blocks.
Keywords: *sanitation, landslide, open pit, monitoring.*

Introduction

This paper presented calculations, assessment and analysis of geotechnical stability of working and finished slopes in open pit "Central ore body," especially in the appearance of geotechnical deformations.
The purposes of these researches are in line with the main task of this analysis, and that is:

- determine the coefficient of reliability,
- stability assessment of the excavated blocks,
- analysis of the geotechnical stability in open pit mine

This includes terrain research and macroscopic assessment of the geotechnical stability of the open pit mine and the excavated blocks with mathematical analysis with modern methods of the geotechnical slope stability in the open pit mine.
In analyzing will use modern methods to define the stability of slopes. The most typical are:
- Bishop method,
- Spencer method and
- Janbu method

GEOMECHANICAL CARACTERISTICS OF THE WORKING ENVIRONMENT

Based on current knowledge and from the engineering-geological viewpoint the open pit mine "Central ore body" is in stable geotechnical field with certain specifics. According to the level of cracking is used Noshpal classification. According the measuring data, the most often are cracks with width 1-2 mm, rarely 3-10 cm.

That clasification is shown below:

Table 1. Classification of cracks

Coefficient of cracking (%)	Level of cracking	Character of cracks
1	2	3
2	Low cracking	Cracks lower then 1 mm, there are no medium and large cracks
2-5	Medium cracking	Near the cracks of 1 mm are present small (2-5 mm) and medium (5-20 mm) cracks
5-10	Large cracking	Near the small cracks, there are large cracks with width 20-100 mm
10-20	Very large cracking	Near the small cracks are present large and very large cracks with width 20-100 mm and more
> 20	Extremely very large cracking	Dominant presence of large and very large cracks

For quantitative evaluation of the frequency of occurrence of the cracks and the system of cracks is used module of cracking (number of cracks on unit meter section of rock). According the results from the examination in the Deposit "Bucim", the size of mentioned parameters is given below:

Table 2. Coefficient, module and level of cracking

Type of rock and ore	Coefficient of cracking (%)	Module of cracking	Level of cracking
1	2	3	4
Andesite	4,1	7,0	Medium cracking
Gneiss	3,8	5,5	Medium cracking
Ore	3,9	5,8	Medium cracking

Based on this classification, the cracks are in the class of small and midle cracks. Furthermore, based on the measurement of fissure system is defines the ratio of cracks, which ranges from 2.8-4.8, and the cracks module that ranges from 2-9.

In the table are presented strenght parameters of the represented members with characterized values:

Table 3. Geomechanical characteristics of working environment

No.	Type of environment	Cohesion (planned condition) C [кPa]	Angle of internal friction φ [°]	Volume weight γ [kN/m³]
1	Changed Gneiss (parallel of foliation) RMR = 37	150.00	33.54	26.20
2	Changed Gneiss (normal of foliation) RMR = 40	310.00	36.17	26.20
3	Andesite RMR = 54	2770.00	43.79	26.70
4	Fault zones RMR = 23	40.00	31.89	22.00

GEOTECHNICAL ANALYSIS OF STABILITY FOR WORKING AND FINISHED SLOPES IN THE EXCAVATED BLOCKS IN OPET PIT MINE " BUCIM"

Analyzed was slope stability in the north, northwest and northeast, respectively, in the area where registered geotechnical instability. An analysis was made in the area covered by the profiles: P-0 - P-0', P1 – P1' и P2 – P2'. The appearing landslide, emerging deformations of the terrain above all material cracking in open pit indicate that geotechnical space is unstable.

Fig.1 Appeared landslide (view from the north-east)

GEOTECHNICAL ANALYSIS

SECTION P0 – P0'

Geotechnical analyses of slope stability are according to three different methods: method of Bishop, method of Janbu and method of Spencer. The results of the analysis are:

Table 4. Geotechnical analysis of the current state of working slopes with Ru = 0.0

Assumed sliding area and	Minimum factor of safety					
Ru=0	S-1		S-2		S-3	
	F	M	F	M	F	M
Bishop	1.227		1.349		1.570	
Janbu		1.172		1.296		1.427
Spencer	1.224	1.221	1.346	1.343	1.559	1.560
Minimum value (Fs)	1.172		1.296		1.427	
Average value	1.211		1.334		1.529	
The condition for stability (Fs>1.3)	NO		NO		YES	

Table 5. Geotechnical analysis of the current state of working slopes with Ru=0.2

Assumed sliding area and	Minimum factor of safety					
Ru=0.2 and assumed NPV	S-1		S-2		S-3	
	F	M	F	M	F	M
Bishop	1.095		1.308		1.447	
Janbu		0.978		1.194		1.265
Spencer	1.102	1.100	1.305	1.304	1.446	1.442
Minimum value (Fs)	0.978		1.194		1.265	
Average value	1.069		1.278		1.400	
The condition for stability (Fs>1.3)	NO		NO		NO	

There was 2 analyses done with current condition for this section with Ru=0 and with Ru = 0.2.

Thus for each analysis, carried out calculation of geotechnical stability with three superiors sliding surfaces: S-1, S-2 и S-3. Analyses show:

1. When Ru = 0 and without the assumed level of groundwater, excavation blocks covered with working slopes of geotechnical section is unstable.
2. When Ru =0.2, excavation blocks covered with working slopes of geotechnical section is unstable. Should be potentiated about:
    a. Most unstable part of the excavated blocks covered by the assumed sliding area S-1, ie it is the entire section.
    b. Rising groundwater level, the pressure in the pores, will continue to cause reduction in the geotechnical stability of the excavated blocks of slopes covered by this section.

SECTION P1 – P1'

Geotechnical analyses of slope stability are according to three different methods: method of Bishop, method of Janbu and method of Spencer. The results of the analysis are as follows:

Table 6. Geotechnical analysis of the current state of working slopes with Ru = 0.0

Assumed sliding area and	Minimum factor of safety					
Ru=0	S-1		S-2		S-3	
	F	M	F	M	F	M
Bishop	1.613		1.444		2.126	
Janbu		1.490		1.355		2.032
Spencer	1.606	1.606	1.436	1.431	2.123	2.122
Minimum value (Fs)	1.490		1.355		2.032	
Average value	1.579		1.417		2.101	
The condition for stability (Fs>1.3)	YES		YES		YES	

Table 7. Geotechnical analysis of the current state of working slopes with Ru=0.2

Assumed sliding area and	Minimum factor of safety					
Ru=0.2 and assumed NPV	S-1		S-2		S-3	
	F	M	F	M	F	M
Bishop	1.290		1.314		1.588	
Janbu		1.166		1.183		1.586
Spencer	1.292	1.297	1.309	1.307	1.586	1.587
Minimum value (Fs)	1.166		1.183		1.586	
Average value	1.261		1.278		1.587	
The condition for stability (Fs>1.3)	NO		NO		YES	

There was 4 analyses done with current condition for this section with Ru=0 and with Ru = 0.2.

Thus for each analysis, carried out calculation of geotechnical stability with three superiors sliding surfaces: S-1, S-2 и S-3. Analyses show:

1. When Ru = 0 and without the assumed level of groundwater, excavation blocks covered with working slopes of geotechnical section is stable.
2. When Ru =0.2, excavation blocks covered with working slopes of geotechnical section is unstable. Should be potentiated about:
    a. Most unstable part of the excavated blocks covered by the assumed sliding area S-1, ie it is the entire section.
    b. Rising groundwater level, the pressure in the pores, will continue to cause reduction in the geotechnical stability of the excavated blocks of slopes covered by this section.

SECTION P2– P2'

Geotechnical analyses of slope stability are according to three different methods: method of Bishop, method of Janbu and method of Spencer. The results of the analysis are as follows:

Table 8. Geotechnical analysis of the current state of working slopes with Ru = 0.0

Assumed sliding area and	Minimum factor of safety					
Ru=0.0	S-1		S-2		S-3	
	F	M	F	M	F	M
Bishop	1.346		1.351		1.568	
Janbu		1.262		1.282		1.464
Spencer	1.337	1.332	1.347	1.343	1.568	1.564
Minimum value (Fs)	1.262		1.282		1.464	
Average value	1.319		1.331		1.541	
The condition for stability (Fs>1.3)	NO		NO		YES	

Table 3-3-2 Geotechnical analysis of the current state of working slopes with Ru=0.2

Assumed sliding area and	Minimum factor of safety					
Ru=0.2 and assumed NPV	S-1		S-2		S-3	
	F	M	F	M	F	M
Bishop	1.302		1.243		1.590	
Janbu		1.132		1.099		1.379
Spencer	1.301	1.306	1.247	1.256	1.590	1.583
Minimum value (Fs)	1.132		1.099		1.379	
Average value	1.260		1.211		1.536	
The condition for stability (Fs>1.3)	НЕ		НЕ		ДА	

There was 2 analyses done with current condition for this section with Ru=0 and with Ru = 0.2.

Thus for each analysis, carried out calculation of geotechnical stability with three superiors sliding surfaces: S-1, S-2 и S-3.

Analyses show:

1. When Ru = 0 and without the assumed level of groundwater, excavation blocks covered with working slopes of geotechnical section is stable.
2. When Ru =0.2, excavation blocks covered with working slopes of geotechnical section is unstable. Should be potentiated about:
    a. Most unstable part of the excavated blocks covered by the assumed sliding area S-2, ie it is the part from section above elevation 540.
    b. Rising groundwater level, the pressure in the pores, will continue to cause reduction in the geotechnical stability of the excavated blocks of slopes covered by this section.

ASSUMED CAUSES OF GEOTECHNICAL INSTABILITY

Based on the recorded state of the site can be singled out suspected causes of geotechnical instability:

- The opening of the lower benches in order to achieve the required capacity of exploitation of ore conditions and further disruption of already disturbed geotechnical material.
- This year is especially moist with large precipitation. Appearances of atmospheric water in open pit, her untimely prevention, and increase the level of underground water and they increase as the causes of geotechnical instability. Accumulated water at the bottom of the open pit, suggesting that the bottom of the open pit, and thus the benches above it, is on the water with a possible increase

in the level of groundwater and pore water pressure. This in turn markedly reduces the geotechnical stability of the trench.

- Geotechnical analyzes so far been made on the basis of data on geo-mechanical characteristics of the work environment that are relatively old and generally unrepresentative of this space. Necessarily is taking a new sample and making a new analysis.
- Almost fully united benches slopes to higher benches (from highest to lowest bench) causes continuous leak of broken material and thus disturbing the voltage standby (appearance of dynamic forces from landslides). With these researches we get information that the terrain is unstable.

CONCLUSION

General conclusions of actual geotechnical analysis:

- It was made geotechnical analysis of 3 different sections (covering current) at 2 general model (Ru = 0 and Ru = 0.2), respectively, calculated by 3 methods (Bishop, Janbu and Spencer).
- There were made 18 calculations for geotechnical stability.
- With analyses is get current state of the working and final slopes and have a value of minimum safety factor of less than 1.3.
- With this information's indicate that the excavated blocks of slopes covered by this analysis sections do not have the necessary geotechnical stability.

Table-1. Geotechnical condition in open pit mine "Central ore body"

No.	Section	Current condition[1]	
		Critical supposing sliding area	F_{min}
1	P0 – P0'	S-1	0.978
2	P1 – P1'	S-1	1.166
3	P2 – P2'	S-2	1.099

Recommendations to reduce the possibility of instability:

- Ensure to be exploited under a ***valid mining project***, in accordance with the dynamics of development, in plan and in depth.
- For any change must be made ***new additional mining project*** that will cover not only the stability of the slope of the excavated blocks, but also changed the geometry, quantity of ore and tailings transport routes and what changed.
- In general, according to the legislation (Norms for surface mining) is not allowed geotechnical unstable benches. Their rehabilitation is necessary, before continuing further exploitation.
- Be sure to use ***methods of contour blasting***.
- To perform the ***re-taking of samples for geomechanical testing***. To re-define the geomechanical and strength parameters of environment.
- It is advisable to make and ***mineralogical - petrographic and chemical analyzes of the sliding material***. To determine the exact composition and above all the presence of possible clay material.

Daily to perform ***geodetic update of slope stability*** by measuring where there already expressed an outbreak of geotechnical instability.

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