DRILLING AND BLASTING TO FORM THE WALL OF THE NON-OPERATIONAL BENCHES OF ELLATZITE MINE

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ABSTRACT. Ellatzite Open Pit Mine is remarkable for its variable lithology, specific geotechnical areas and a wide variety of rock strengths in the processed rock body. This variety is a challenge when it comes to designing, drilling and blasting for they need to cover a large scope of criteria. Having in mind the scale of processing (space and depth), it is necessary to sustain a long lasting wall stability. After multiple consultations and knowledge exchange, Mine Management made a decision to use 24-meter-long pre-split holes which changed the design for drilling and blasting of fields at a final project contour of the operational benches and helped securing the wall stability.

Keywords: lithology, design for drilling and blasting

ПРОБИВНО-ВЗРИВНИ РАБОТИ ЗА ОФОРМЯНЕ НА ОТКОСА НА НЕРАБОТНИТЕ СТЪПАЛА В РУДНИК „ЕЛАЦИТЕ“

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РЕЗЮМЕ. Рудник „Елаците“ се отличава с многообразна литология, специфични геотехнически зони и широк диапазон от стойности на якост на разработвания масив. Това разнообразие е предизвикателство при проектирането на пробивно-взривни работи, които да покриват множество критерии. Предвид мащабите на разработване (по площ и дълбочина) е необходимо осигуряването на дълготрайна устойчивост на откосите. След проведени консултации и обмяна на опит, ръководството на рудника взима решение за изпълняването на 24-метрови контурни сондажи, които променят проектирането на паспортите за ПВР при взривни полета до проектен краен контур по работните хоризонти и спомагат за осигуряването на стабилитета на откосите.

Ключови думи: литология, паспорт за ПВР

Introduction

When excavating ore deposits, it is of primary importance to secure the walls of the benches for the whole lifetime of the mine. The output data for determining the wall stability are complexity of information about the nature and technical mining conditions and factors, characterizing the objects in question. There are many methods to calculate the stability profile of the walls, but none of them gives precise results. This is due to their imperfection and the probabilistic nature of the output data. The majority of those methods are based on the assumption for the existence of a certain slip motion surface in the wall slope where the rock movement can occur.

In Ellatzite Open-pit Mine, the wall profile is with terrace-like form, consisting of non-operational benches, whose parameters, based on the physio-mechanical properties of the rock diversities, are as follows: project height of the benches at final contour H=15 m or H=30 m; safety berms width B=12-20 m and slope angle a=65º-75º (in weak rock zones a=55º).

There are two stages of processing to achieve non-operational benches with project height of H=30 m (1st and 2nd), with sub benches whose height is H=15 m. Providing long term wall stability in Ellatzite Mine ensures safe processing and potentially long term exploitation.

Rock mass geology in Ellatzite Open-pit Mine

When designing the drilling and blasting activities there is a need to consider the geological and geotechnical information for the processed rock diversities which will give the main directions when choosing:

- Boreholes diameters and boreholes patterns
- Blasting technology
- Explosives
- Necessary quantities of explosives in a series for detonation
- Delay grades (surface, when applying NONEL technology and delays for the electronic detonators when applying ELECTRONIC technology) for detonation of the different explosive charges.

For this purpose, all production benches of the mine, be it ore or waste, are mapped by the Geotechnical Department of Ellatzite Mine and described in terms of: lithology of the rock body, physio-mechanical properties of the rocks, tectonic faults, block structure and cracks of the rock bodies, mainly consisting of: granodiorites, porphyrites, shists and philites. The compression strength values are different with the different rock types. Most of them have values of s=120-150 MPa. A blastability matrix has been created, based on the information of all mapped benches in the mine (table 1). This matrix divides the rock bodies into nine different classes, depending on their block structure and compression strength, that determine the borehole patterns, technology of detonation (NONEL or Electronic) and the quantities of explosives when creating the drilling and blasting design.

The main statement is structured into different sections, possibly divided by a separate title each. Each statement needs: research thesis and hypothesis, applied methods, main achieved results and discussion. The conclusion should not match the resume word by word.

Table 1. *Rock bodies classification in Ellatzite Open-pit Mine according to the blastability matrix*

BLOCK STRUCTURE			Mpa	COMPRESSION STRENGTH
0m - 0,3m	0,3m - 1m	1m <		
PHILITES (40 MPa)	PHILITES (40 MPa)	PHILITES (40 MPa)	0 - 60	
SHISTS IN WET CONDITIONS (87 Mpa)	SHISTS IN WET CONDITIONS (87 Mpa)	SHISTS IN WET CONDITIONS (87 Mpa)	60 - 120	
SHISTS IN DRY CONDITIONS (123 Mpa) PORPHYRITES (126 Mpa) GRANODIORYTES IN DRY CONDITIONS (147 Mpa) GRANODIORYTES IN WET CONDITIONS(133 Mpa)	SHISTS IN DRY CONDITIONS (123 Mpa) PORPHYRITES (126 Mpa) GRANODIORYTES IN DRY CONDITIONS (147 Mpa) GRANODIORYTES IN WET CONDITIONS(133 Mpa)	SHISTS IN DRY CONDITIONS (123 Mpa) PORPHYRITES (126 Mpa) GRANODIORYTES IN DRY CONDITIONS (147 Mpa) GRANODIORYTES IN WET CONDITIONS(133 Mpa)	120 <	

On Figure 1, you can see the lithology of one of the workout benches with tectonic faults and the orientation of their space distribution. There is a structural geological diagram (left part of the figure), which represents the crack distribution in the rock mass and their frequency. For each of the workout benches there could be several diagrams of that kind but there are not randomly situated in the bench plans. They are placed in the areas with supposed deformation processes and the space distribution direction in case of activation. The engineers engaged in drilling and blasting design take this information into account when preparing the drilling and blasting design.

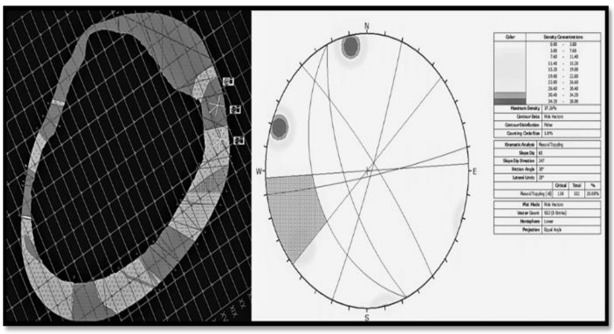

Fig. 1. Plan view of a mapped production bench -1090 – in Ellatzite Mine and structural geological bench diagram

Drilling and blasting activities to form the wall of the non-operational H=30 m benches

The idea of a good drilling and blasting design, providing quality of board formation with minimal damage is to undertake certain measures to: reduce wall damage (defining the quantities of explosive in the boreholes and the optimal timing for initiation of the charges); protecting the integrity of the upper crest of the safety berms (no boreholes are situated in the project upper crest of the safety berms) which increases the capacity of the safety berms to “take up” the falling rocks and to provide the necessary protection for the machines and the staff, working underneath.

On Figure 2, you can see a comparison between wall formation of the non-operational benches with pre-split holes in both stages of workout (a) and using pre-split holes only in the first stage (b). With option (a) from Fig. 2, you can see the formation of the berm between the two sub benches along the non-operational bench, whose width varies between B=1.5 – 2.5 m. The pre-split holes in this wall formation model have a designed depth of L=16 m, designed angle a=75º and spacing a= 1.5 – 2.5 m.

Fig. 2. a) results after using pre-split holes in 1st and 2nd stages of working with sub benches; б) results after using pre-split holes only in 1st stage of working with sub benches.

With option (b) from Fig. 2, to form the wall of the non-operational bench with height of H=30 m, the pre-split holes are done once. This wall formation model has been applied in the recent few years, showing considerably better results in the formation of the wall geometry of the non-operational benches. The berm, characteristic for option (a) from Fig. 2 is no longer available. The wall is a bit more inclined giving opportunities for a more even distribution of the possible deformation processes in the rock mass. Having in mind the diversity of the lithology in Ellatzite Mine and he rock classification according to the blastability matrix (table 1), there are different borehole patterns in the drilling and blasting designs, with different quantities of explosives and different blasting technologies (NONEL or Electronic). In the present report there will be presented drilling and blasting activities for wall formation of non-operational benches with height of H=30 m and wall angle of α=65º, in a rock body of granodiorite. The diameters iused for drilling are d=165 mm (push-button bits) and d=250 mm (tripple-roller bits). Hole networks: for pre-split a=1,8 m; for production 5,5 x 6,5 m. For the purposes of the drilling and blasting, checkered patterns are used.

Use of explosives

Ellatzite Mine have their own Explosives factory that produces the necessary quantities of explosives for its production purposes. The explosive used for the pre-split holes loading is cartridge emulsion Ellatzit 710. The sleeve of the cartridged explosive is a three layered, antistatic cross-shaped foil with a diameter of d=40 mm and L=10 m. The weight of the explosive Ellatzit 710 for a cartridge with the given size is Q=16 kg. Two cartridges of Ellatzit 710 are put alongside each pre-split hole, taking up 20 m of its length (83%). Only Electronic technology is used to detonate the explosives in the presplit holes, produced by Austin Powder. The explosive is sensitive to detonators and there is no need for boosters. The time interval for detonation of the charges in the pre-split holes is in milliseconds, in accordance with the physio-mechanical and geotechnical properties of the rock body where the pre-split holes are. In this case of a rock body, consisting of granodiorites, 160 kg of Ellatzit 710 is used in a series, where the interval between the different series is t=15 ms. The time intervals for both pre-split and production holes are analyzed in terms of the caused seismic through investigations made by Explosivprogres – GTM Ltd.

Table 2. *Explosives used in the 1st and 2nd stage of working a non-operational bench H=30 m in Ellatzite Mine*

Explosive	Type of explosive	Bulk density, кg/m^3	Critical diameter, mm, not more than	stable diameter, mm not more than	Optimal middle detonator	Velocity of detonation, m/s
Ellatzit 710	cartridged emulsion	1100-1220	до 51*	над 51**	not less than KD №8	not less than 5000
ANFO E	naphtonitrate ruoghly disperse	750-820	60	100	400 g cartridge TNT	not less than 3000
Ellatzit 3400	emulsion	1150-1280	80	120	400 g cartridge TNT	not less than 4300

* - with hot emulsion density = 1.08 ± 0.03 g/cm³ ; with cooled emulsion density = 1.12 ± 0.03 g/cm³

**- with hot emulsion density = 1.14 ± 0.03 g/cm³ ; with cooled emulsion density = 1.18 ± 0.03 g/cm³

The technological capacity of the Explosives Plant in Ellatzite Mining Complex allow the production of cartridges of Ellatzit 710 with different diameters, length and weight. There are several sizes according to diameter: 28 mm; 32 mm; 36 mm; 50 mm; 65 mm и 90 mm.

Drilling throughout the stages of wall formation of a non-operational bench in Ellatzite Mine with H=30 m height, using sub benches of H=15 m

One of the conditions for wall control and damage decrease is to use pre-split holes in order to disperse the energy and sending part of it vertically up when blasting final board designs. The pre-split holes are drilled with diesel-hydraulic drilling machines with d=145 mm or d=165 mm push-button bits. According to the compression strength of the rock types, where the pre-split holes will take place and the diameter of the drilling instrument, the distances between them are described in Tables 3 and 4.

Table 3. Spacing between pre-split holes in different rock types, made with *d=165 mm* drill bit.

Drill bit Rock body	Compression strength, MPa	Spacing, m
Philites	40	2,5
Shists	87	2
Porphyrites	126	1,8
Granodiorites	147	1,8

Table 4. Spacing between pre-split holes in different rock types, made with *d=142 mm* drill bit.

Rock body	Compression strength, MPa	Spacing, m
Philites	40	1,8
Shists	87	1,6
Porphyrites	126	1,5
Granodiorites	147	1,5

After drilling and blasting of the pre-split holes, the rest of the holes needed for the final wall formation are done. For these purpose diesel-hydraulic drilling machines are used with diameter d=142-250 mm. The applied hole patterns are checkered. The location of the holes is set by the surveyors after importing the coordinates of each hole in GNSS- receiver. The majority of diesel-hydraulic drillers in Ellatzite Mining Complex that use d=250 mm drill bits have integrated system for positioning over the design coordinates of the holes, with accuracy of positioning up to 10 cm. Fig. 3 and Fig. 4 show the applied types of boreholes and the spacing between them.

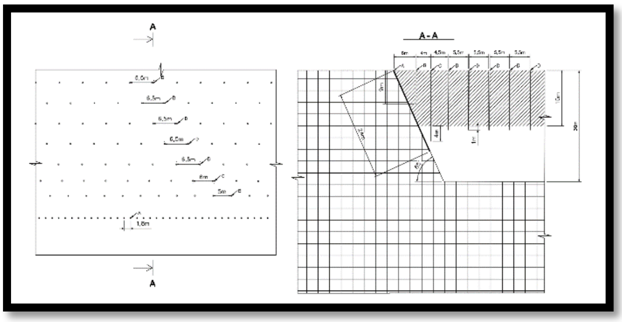

Fig. 3. Wall formation drilling, performed in the 1st stage of working the non-operational bench with H=30 m height in Ellatzite Mine

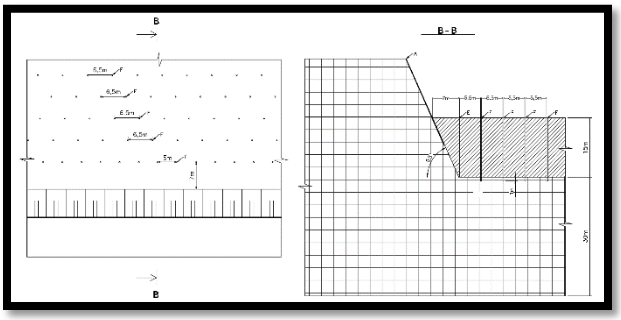

Fig. 4. Wall formation drilling, performed in the 2nd stage of working the non-operational bench with H=30 m height in Ellatzite Mine

When the resistance line (W) is too high the production holes (categories D and F) are done with design angle different than 90º (from 75º to 85º).

Table 5. *Realized boreholes, used for wall formation of non-operational bench with H=30 m height in Ellatzite Mine*

Blasthole category	Stage of working	Blasthole type	Diameter, mm	Project angle, ...°	Depth, m	Cartridge, pcs.	Quantity of explosive per hole (dry or wet), kg			Charge construction	Stemming, m
							E-710	E-3400	ANFO		
A	1st	presplit	165	65	24	-	32	-	-	continuous	-
B	1st	buffer	165	90	9	1	-	120	-	continuous	-
C	1st	buffer	165	90	19	2	-	400	-	continuous	5
D	1st	production	250	90	16	2	-	770	440	continuous	5
E	2nd	buffer	165	90	15	2	-	220	-	continuous	-
F	2nd	production	250	90	16	2	-	770	440	continuous	5

In the 2^{nd} work stage (fig. 4), the buffer holes, category E, are placed over the toe of the safety berms with no subdrilling. The stemming material for both work stages is a fraction with rock pieces size up to 20 mm. The material for the stemming is mine mass from Ellatzite pit, crashed by a mobile crasher situated on the territory of the pit itself.

Control seismic research for the impact of blasting on the walls of Ellatzite Mine

In Ellatzite Open-pit Mine there is a large variety of the geological, hydrogeological and other conditions that reflect the behavior of the rock masses forming the pit walls. When making seismic researches, they use seismic waves generated by the blastworks in the mine.

The control seismic researches are made by Explosiveprogres-GTM Ltd. They use equipment from „Instantel"(Canada) and „Nomis" (USA). They provide with the opportunity of the immediate result speed of movement (vibration, fluctuation) V. The explosive seismic impact on the pit walls is a result of dynamic pressure and release from the seismic waves through the rocks, caused by the production blasting. In these cases the dynamic pressure and release of the rock body goes according to the same physical law, in the scope of the elastic behavior of the rocks which doesn't lead to residual deformations. For rates above this tension, the pressure and release of the rock body happens according to different physical laws, leading to formation and accumulation of residual deformations. This accumulation is typical for multiple blasting and can lead to loss of stability and rock downfall.

The deformational properties of the rocks are of crucial significance when choosing the allowed speed of movement (vibration, fluctuation) V. The speed of movement (vibration, fluctuation V, depending on the rock break characteristics, shows that when V is up to 20 cm, there are no observed breaks (damages) in hard rocks.

Conclusion

This drilling and blasting model has one key element that plays an important role in DB designing and it is the pre-split holes with L=24 m depth. They have more advantages compared to the no longer applied L=16 m, α=75° ones (used for double benches). This type of boreholes helps avoiding drilling underneath the walls according to designed toe in the 2^{nd} stage of the working with sub benches. There are also economic advantages since this helps reducing the amount of drilling. Last, but not least, their main purpose to form the walls of the non-operational benches is fulfilled and the results are technically and economically efficient.