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Professional paper

OPTIMIZATION OF RING BLASTING IN SUBLEVEL STOPING GOLD MINE

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Abstract: Important parameters that describe successful sublevel stoping operation are optimal fragmentation and low damage of rock mass around stopes. In current state of operation fragmentation of blasted material is not optimal since high percentage of fragments are oversized which requires additional sizing. Also, excessive damage of surrounding rock mass is found. By proposing new blasting pattern with slightly increased amount of drilling, but with decreased hole diameter decrease of explosive usage is obtained for more than 100kg. Along with better charge distribution it is expected that rock mass damage is to be decreased as well.

Keywords: drilling and blasting; ring blasting; sublevel stoping; fragmentation;

1 INTRODUCTION

Lece mine utilizes sublevel stoping mining method with drilling and blasting as main excavation technology. Drill holes (75mm) are drilled in ring/fan pattern from the level of sublevel drift using hydraulic hammer. ANFO is used as main explosive, while initiation is done using detonating cord and electric detonators.

Main problem that mine is facing is oversized fragments that require secondary scaling before loading and haulage. Also, excessive damage of surrounding rock mass leads to frequent instabilities. Blast fragmentation has been widely investigated and some of notable research results are presented by Goodarzi et al. (2015), Esen et al. (2003), Cho and Kaneko (2004) and Torbica and Lapcevic (2014b, 2016a). Excessive damage to surrounding rock mass is also one of the huge problems that occurs in underground mining since it impact the stability of the openings and stopes. Some of important works in this area are presented by Olsson and Bergqvist (1996), Fullelove et al. (2016) and Torbica and Lapcevic (2015, 2016b).

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Reasons for those problems is nonoptimal blasting pattern, sequence of initiation and delays between series. Several authors proposed methodologies for ring blast design such as Onederra and Chitombo (2007) and Wang et al. (2018). Main methodology that is used for blasting optimization is presented by Torbica and Lapcevic (2014a, 2018).

2 CURRENT STATE OF DRIIL AND BLAST OPERATIONS

Currently drill and blast operations are performed using the blasting pattern illustrated in Figure 1. Inaccurate drilling is main problem that is faced along with poor charge optimization and initiation sequence. All of this led to oversized fragmentation and high requirements for scaling of oversized blocks.

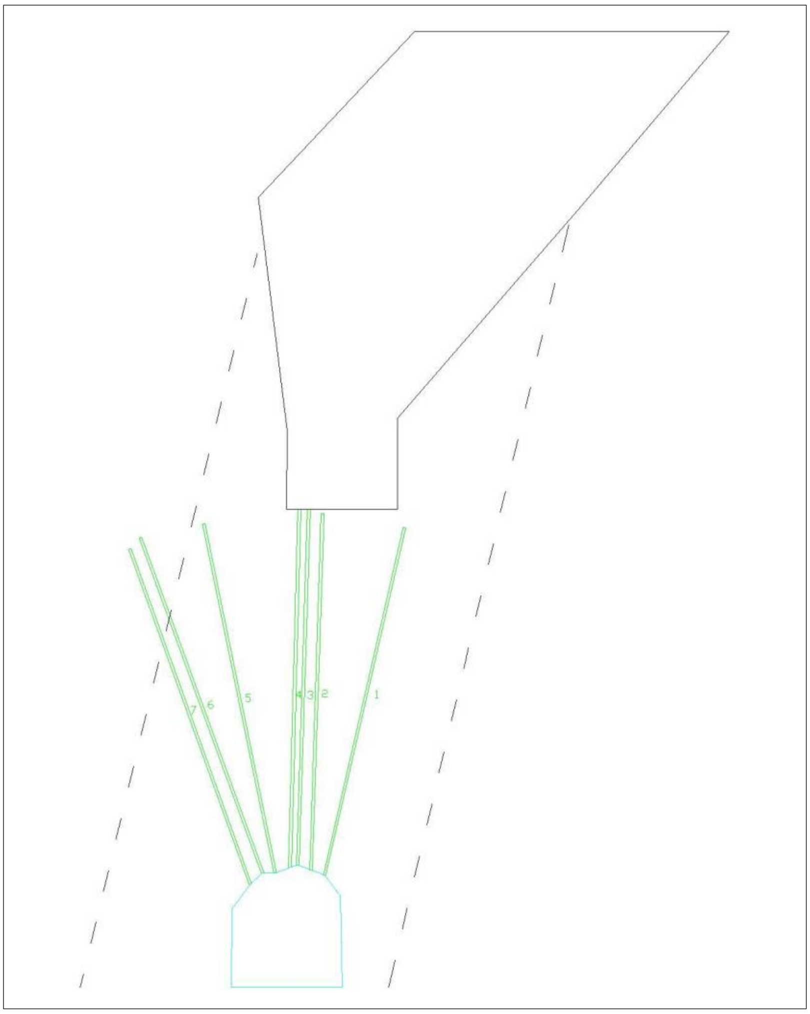

Figure 1 Current blasting pattern

Central drillhole number 4 is drilled first until upper drift is reached. Other drillholes are drilled in same length as first hole. Inclination of face is 80° and drillholes follow this inclination. After drilling, all holes are charge with ANFO and equipped with initiation system. Stemming of the borehole is around 30cm long and often improvised. Initiation of explosive charge is performed by detonating cord which is initiated by electric detonator at once. Drill and blast parameters are illustrated in Table 1.

Table 1 Current drill and blast parameters

No.	Borehole length (m)	Charge length (m)	Explosive mass (kg)
1	10.00	9.7	40.69
2	10.00	9.7	40.69
3	10.00	9.7	40.69
4	10.00	9.7	40.69
5	10.00	9.7	40.69
6	10.00	9.7	40.69
7	10.00	9.7	40.69
$\sum =$	**70.00**	**67.9**	**284.83**

3 SUGGESTED BLASTING PATTERN

Figure 2 illustrates the newly suggested blasting pattern with charge design and initiation sequence illustrated in Figure 2. In this case, 64mm diameter holes are used instead of 75mm. Detonation pressure on the borehole wall is calculated as given by equation 1.

$$P_d = \frac{\gamma \cdot D^2}{4.5} = \frac{0.95 \cdot 3.5^2}{4.5} = 2.6GPa \tag{1}$$

Where:

ρ – explosive density (g/cm^3)
D – detonation velocity (km/s)

Burden is calculated using equation 2.

$$B = \frac{0.17 \cdot P_d \cdot r_h}{k \cdot \sigma_t} = \frac{0.17 \cdot 2.6 \cdot 32}{1.11 \cdot 12.65} = 1m \tag{2}$$

Where:

P_d – borehole pressure (GPa)
r_h – borehole radius (mm)
σ_t – tensile strength (MPa)
ν − Poisson ratio (ν = 0,2)

Coefficient k is calculated as follows:

$$k = \frac{1-\nu}{(1+\nu)\cdot(1-2\nu)} \tag{3}$$

Drilling rig rotation center is fixed at about 1.5m from the drift bottom, approximately at the center of the drift cross section. Blasting pattern details are given in Table 2.

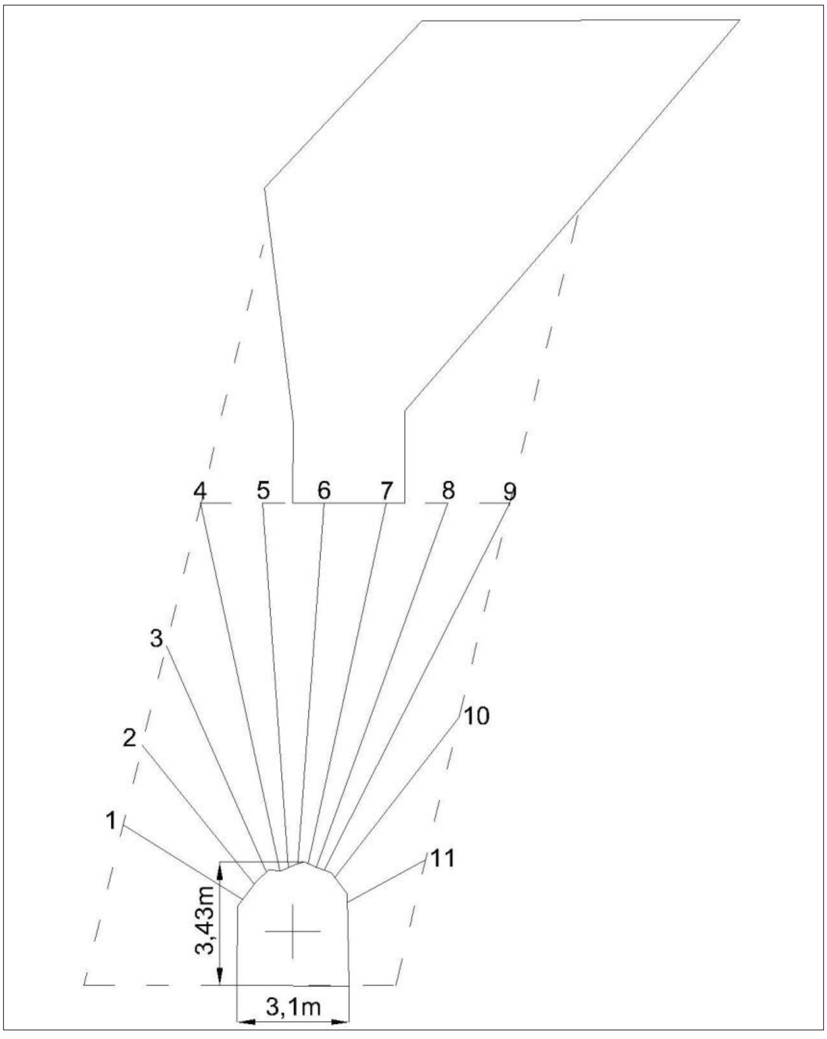

Figure 2 Suggestion of new blasting pattern

Table 2 Blasting pattern details

Hole No.	Hole length (m)	Inclination (°)
1	3.92	148
2	4.96	127
3	6.86	112
4	10.44	100
5	10.15	92
6	10.05	86
7	10.24	78
8	10.75	70
9	11.42	63
10	5.63	52
11	2.46	28
∑ =	**86.87**	/

Explosive is charged using pneumatic ANFO charger and for initiation TNT based primer patron is used. Primer is located at the beginning of the borehole.

Charge optimization is preformed to avoid excessive usage of explosive and to achieve even fragmentation of blasted material. Charge optimization methodology consists of examination of crossing points of each charge burden lines/cylinders. Crossing point of two burden zones means limit for charge length. All hole are filled down to the 0.7m or 0.7B from the drift roof. Table 3 presents the charge lengths and amounts of explosives per each blasthole.

Table 3 Charge lengths and explosive amounts per each blast hole

Hole No.	Charge length (m)	Explosive mass (kg)
1	3.21	9.81
2	2.80	8.56
3	3.78	11.54
4	9.72	29.68
5	4.82	14.72
6	9.28	28.36
7	4.63	14.14
8	4.39	13.41
9	10.71	32.72
10	2.27	6.93
11	1.67	5.10
∑ =	**57.26**	**174.97**

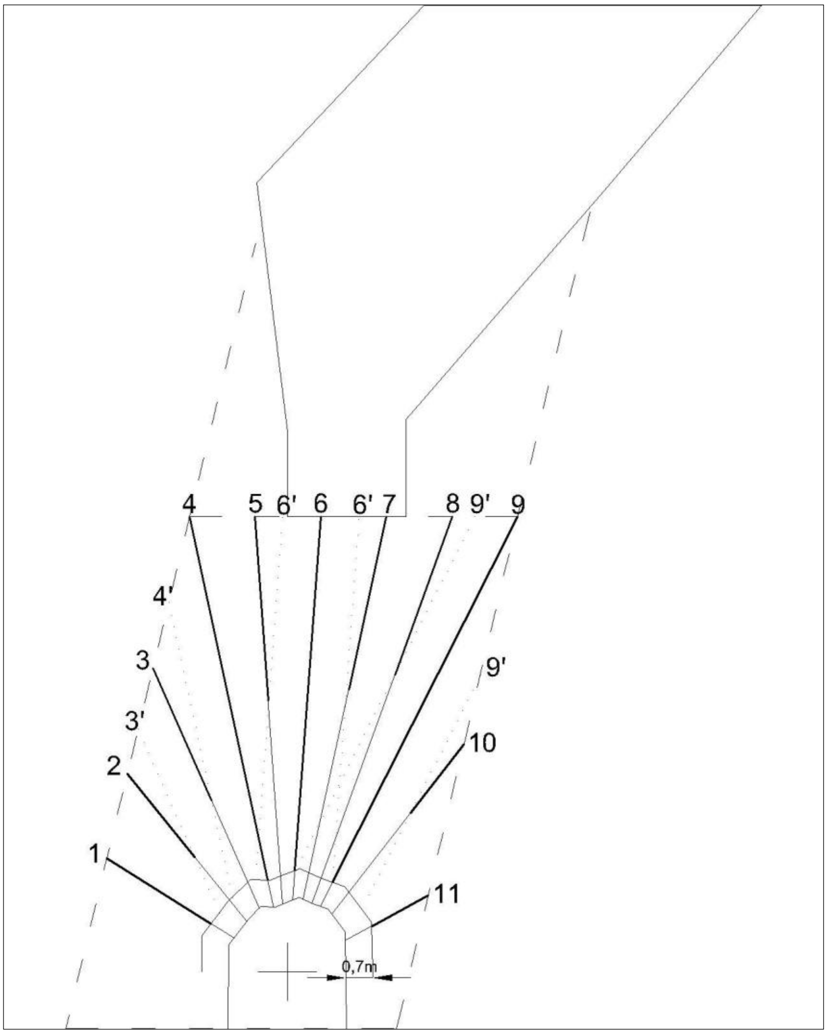

Figure 3 Charge design scheme

Since ore body shape is often changed blasting pattern will be adjusted for the exact situation in-situ. Face of the stope will be vertical instead of 80 degrees in current state. Burden will remain same for each case, while hole geometry may change according the situation.

Primer is located at the beginning of the charge since final detonation velocity though the explosive charge is reached at the distance of around 6 holes diameters from the place of initiation. Primer diameter should not be smaller than 70% of hole diameter.

Initiation sequence assumes that initiation starts from the central hole 6 and continues towards the side holes 1 and 11.

4 CONCLUSION

Current drill and blast operation results in non optimal fragmentation and excessive damage of surrounding rock mass. Suggested improvements assume better spatial disposition of the blast holes and more even explosive charge distribution. Diameter of holes is decreased while total length of drilling is slightly increased. However, due to diameter decrease it is expected that drilling time will not be significantly increased. On the other side, quantity of explosive is reduced for more than 100kg. This will provide better results in means of reduced damage of the stope walls, better economical results since explosive usage is significantly decreased, and handling and storage of explosives will be much easier. It is to be observed what fragmentation optimization outcome would be obtained.

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