Application of controlled blasting (Pre-Splitting) using large diameter hole in Sarcheshmeh copper mine

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ABSTRACT

Due to competitive minerals market, cost effective mining is of a prime importance. In the direct mining costs, in open pit mining, drilling and blasting are one of the biggest single line items in mining budget. In recent years, the tendency has been to minimize mining costs by reducing costs for blasting in which using controlled blasting on the final wall of an open pit mine is also involved.

In the past few years, research has been developed to replace small diameter controlled blasting holes by large diameter holes as the size of production blasting holes due to costs reduction concerns as well as avoiding various drilling equipment.

In Sarcheshmeh copper mine, pre-splitting controlled blasting technique was applied using long hole diameter of 251 mm. 8 tests were carried out to obtain the optimum values for parameters such as spacing, charge length (decoupled or decoupled-deck), coupling ratio and stemming regarding different types of rocks. Accounting for stability and costs effectiveness, the results achieved were very promising.

1-INTRODUCTION

There are a variety of effects produced by a blast, some of which are desirable as they represent useful work, other consequential effects which are non-productive and undesirable but inevitable. During blasting process, almost 80% of energy (Berta, G, 1990) transmitted to the rock is lost in undesirable effects (over break, vibration, air blast). In production blasts, objective is to produce a certain fragmentation of rock as less expensively as possible and therefore breakage behind the hole is sometime regarded as free muck. This non-discrimination characteristic does, however, become a problem when blasting is in vicinity of pit perimeter.

On pit wall stability, blasting has less of an influence than geology and ground water. Of course, the geology of a pit cannot be change but blasting is usually the factor that can be controlled most. As production blasts approach a designed pit wall, there is a usually distance within which mine operators should be concerned with protection rather than production. In working area close to the designed pit wall, blasts on a given bench should consist of controlled blasting. In controlled blasting techniques, there is a strong economic reason to achieve the required levels of soundness and smoothness at the lowest possible cost. The best way to achieved that is by utilising blasting knowledge and expertise to control the adverse effects of using large diameter production blast holes, charged with bulk explosives, as close as possible to the designed pit wall.

In Sarcheshmeh copper mine, as one of largest open pit copper mine in the world with 60000 ton/day ore production, located in 55 Km south of Rafsanjan, Kerman, Iran (Figure 1), some parts of the mine, in particular the west wall facing a critical stability problem, which is controlled by large geological structures (dykes and major faults) and unfavorable hydrogeological conditions, and is likely to be more reduced by the deepening of the pit from 300m to 800 m (based on expansion plan)(Mansouri, H, 2000). In this condition, the production blasts carried out in vicinity of pit wall can contribute to worsen the mine stability. This research consist of selecting and designing a controlled blasting method using large diameter hole (251 mm) in different rock mass conditions in Sarcheshmeh mine. The condition was wet and the explosive used was Emulan. For a product blasting in Sarcheshmeh, bench height, hole diameter, stemming and sub drilling 12.5 m, 250 mm, 8 m and 3.5 m respectively were used. The blasting patterns are being used 7m×9 m, 7.5m×9.5m and 8m ×10 m.

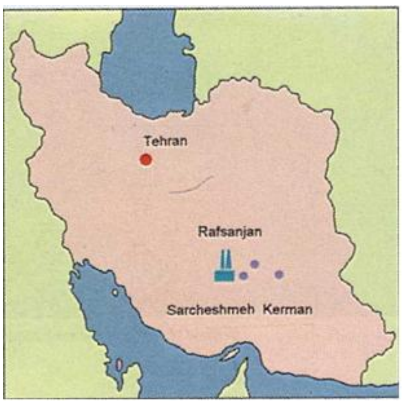

Figure 1: Location of Sarcheshmeh copper mine

2-GEOLOGY OF SARCHESHMEH COPPER MINE

Sarcheshmeh deposit extends on an area of 1700×2900 m^2 with a cut off 0.25%. Because of presence of divers geological structures and different types of rock alteration in Sarcheshmeh region, rock mass is very heterogeneous. There two principal mineralized rock types that are: Andesit (host rock) and Sarcheshmeh Porphyry (intrusive). The deposit was crossed by the dykes that play a fundamental role in behavior of rock mass (Figure2).

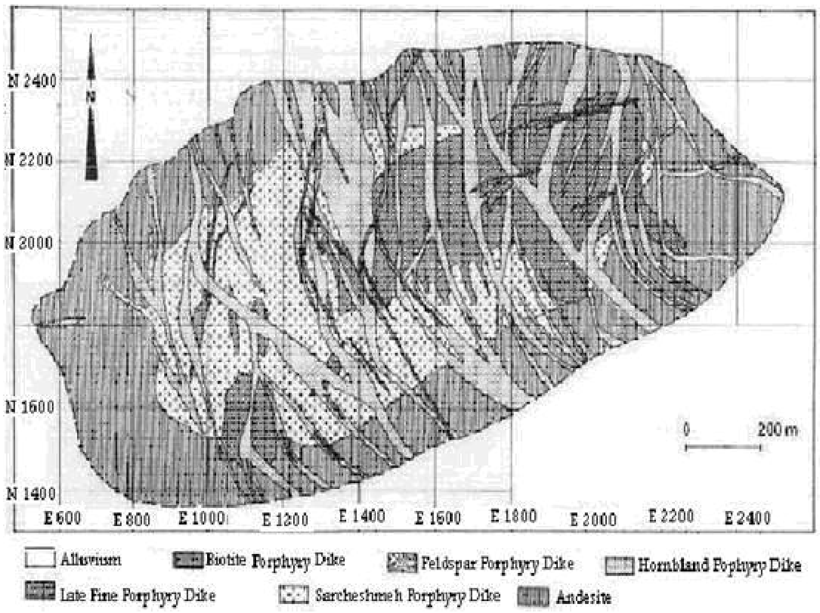

Figure 2: Sar Cheshmeh copper mine deposit at level 2400m.

According to the work carried out by Eslami (Eslami, M, Asadi pour, M, Taheri, A, 2005), all of the rocks in final wall of Sarcheshmeh copper mine are Andesit types. Based on the degree of alteration, geomechanical properties of Andesits are as in Table1.

Table 1: The classification of Andesites in Sarcheshmeh copper mine according to unaxial compressive strength and point load index (Eslami, M, Asadi pour, M, Taheri, A, 2005)

Specification of Rocks	*Related Alteration Degree*	*Unaxial Compressive Strength (MPa)*	*Point Load Index (MPa)*
Unaltered & Unweathered	Fresh	85-120	8-11
Propylitic	I	60-85	5.5-8
Poor Biotitization & Propylitic	II	40-60	4-5.5
Phyllic (High Silisification)	III	25-40	2.5-4
Phyllic	IV	15-25	1.5-2.5
Phyllic & Biotitization	V	1-15	0.5-1.5
Argillic	VI	<1	<0.5

3-PERIMETER BLASTING METHODS

Regarding to the firing sequence, perimeter blasting techniques may be divided in two different groups, as in Figure 3 (modified after Berta, G, 1990).

- Controlled blasting, where the profiling shots are fired after the production rounds.
- Pre-cutting, where the profiling shots are fired first and thus create a break or discontinuity between the rock to be blasted and that which is to remain in place.

In pre-splitting method, a row of parallel holes very close to another, drilled along the excavation perimeter. These holes are charged with deck or decoupling form of charge. The best result is obtained in homogenous rock with high compressive strength.

Some of advantages of this method are:

- Number of boreholes are less than other controlled blasting ,
- Reduced air blast,
- Monotonousness and beauty of wall after blasting,
- Reducing and minimizing cracks that produced behind the pre-splitting row.

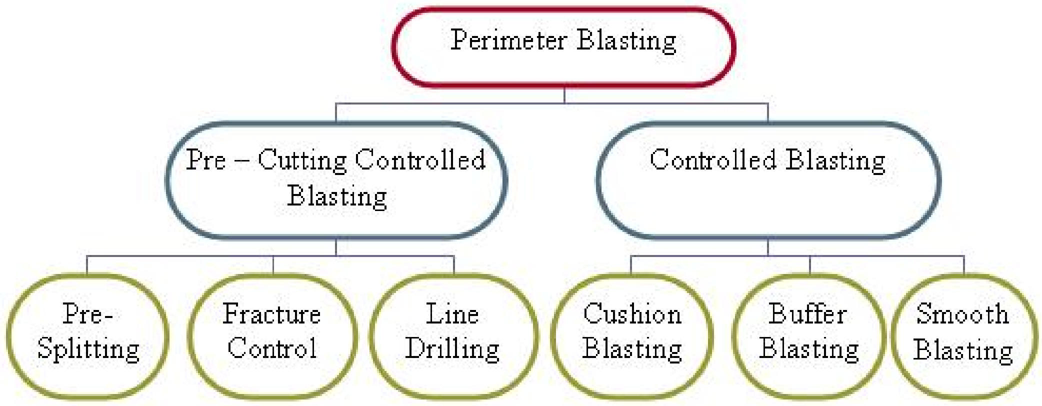

Figure 3: Perimeter blasting techniques

4-USING PRE-SPLITTING TECHNIQUE IN SARCHESHMEH COPPER MINE

With the advantages of pre-splitting technique, it was adopted to carry out the controlled blasting in the perimeter of Sarcheshmeh copper mine.

Conventional hole diameter used for pre-splitting row is small diameter holes. In recent years, due to economic concerns, tendency has been using large diameter holes for pre-splitting row and the same as production blasting.

With no exception for Sarcheshmeh copper mine, it was decided to use hole diameter of 251 mm, which was the most used in production blasting in Sarcheshmeh mine.

Regarding to blast condition and type of explosive, energy reduction in holes in pre-split row was achieved using decoupled charging. PVC pipes with various diameters were used to obtain proper decoupling ratios (Figure 4).

Figure 4: PVC pipe with rubber rings

Rubber rings were used to centralise the pipes in the holes as shown in Figure 5

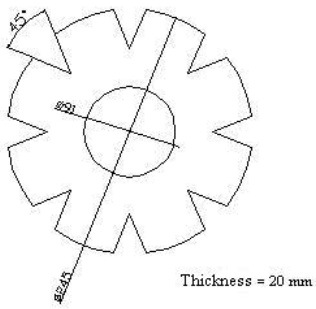

Figure 5: A view of rubber ring used

5-CHARGE CALCULATION

As a starting point, to calculate hole loading density the following equation was adopted (Berta, G, 1990):

$$Q=0.875\ S^2 \qquad (1)$$

Where,

Q: Loading density (kg/m)

S: Spacing (m)

Based on the values in literature (Hustrulid, W, A, McCarter, M, K,VanZyl, D, J, A, 2000), spacings of 3m and 4m were selected to do primary estimations. A loading density of 7.3 kg/m and 13 kg/m were obtained for spacings 3m and 4m respectively. Two-diameter of PVC pipe, available in the site were 110mm and 90 mm. Pipes with diameter 110 mm and 90 mm give a loading density of 11.4 kg/m and 7.6 kg/m respectively. For the tests using spacing 3 m, the pipe diameter of 90 mm was selected. For spacing 4m, the pipes with diameter of 110 mm were used.

On the other hand, in pre-splitting method, to produce a crack between holes, the hole pressure has to be equal to the dynamic tensile strength of rocks (that is, in general, 5-13 times of static tensile strength (Jimeno, C, L, Jimeno, E, L, Carcedo, F, J, A, 1995)). Having the dynamic tensile strength (estimated from static tensile strength), decoupling ratio and geometric parameters, the charge length may be estimated based on the following equations (Liu, Q,2002):

$$P_w = \frac{2\rho_w C_w}{\rho_w C_w + \rho_r C_r} P_B \quad (2)$$

$$P_B = P_e \left[\sqrt{\frac{L_e}{L_B}} \times \frac{r_e}{r_b} \right]^{2.4} \quad (3)$$

$$P_e = 228 \frac{\rho D^2}{(1+0.8\rho)} \quad (4)$$

Where,

P_w: Pre-splitting hole pressure in a wet condition (MPa)

P_e: Detonation and gas pressure (MPa)

P_B: Pre-splitting hole pressure (MPa)

L_B: Length of hole (m)

L_e: Length of charge (m)

r_e: Diameter of charge (mm)

r_b: Diameter of hole (mm)

ρ : Density of explosive (gr/cm^3)

D: Velocity of detonation (m/s)

ρ_w : Density of water

ρ_r : Density of rock

C_r: Wave velocity in rock (m/s)

C_w: Wave velocity in water (m/s)

Regarding to dynamic tensile strength values of Sarcheshmeh rocks types and spacing between holes, the charge length calculated for pipe with diameter of 110 mm was small (it cab be seen in the next section). It was resulted in adopting two methods of charging: decoupled–deck charging and decoupled–continuous charging. The first method was used while using pipe diameter of 110 mm. The decoupled–continuous charging was used while pipe with diameter of 90 mm was planed.

6- EXPERIMENTS AND RESULTS

The tests carried out were divided in two groups as below:

1- Tests using pipes with diameter of 110 mm and deck charging.
2- Tests using pipes with diameter of 90 mm and continuous charging.

6-1- Deck charging tests

Three tests were carried out using deck charging. But due to different problems, faced at the site, the parameters set for two first tests, such as hole length, stemming, uncontrollably were changed at the field and the results obtained were not favorable. . For the third test, as an example, the charge calculation was preceded as follows:

Static tensile strength of rock was obtained about 3.5 MPa and dynamic tensile strength of rock was estimated 17-45 MPa. Charge length was calculated based on following data and Equations 2, 3, and 4.

ρ_w =1 gr/cm^3 ρ_r =2.78 gr/cm^3 C_w =1400 m/s C_r =3800 m/s

P_w= 40MPa D= 4200m/s ρ =1.15 gr/cm^3

$$P_w = \frac{2\rho_w c_w}{\rho_w c_w + \rho_r c_r} P_b = \frac{2\times 1\times 1400}{1\times 1400 + 2.78\times 3800} = 0.234 P_b \Rightarrow P_b = 171\, MPa$$

$$P_e = 228\frac{\rho D^2}{(1+0.8\rho)} \Rightarrow P_e = 228\frac{1.15\times 4200^2}{(1+0.8\times 1.15)} = 2408\, MPa$$

$$P_b = P_e\left[\sqrt{\frac{l_e}{l_b}\times\frac{r_e}{r_b}}\right]^{2.4} \Rightarrow 171 = 2408\left[\sqrt{\frac{l_e}{12}\times\frac{110}{251}}\right]^{2.4} \Rightarrow L_e = 6.8\, m$$

A summary of results obtained can be found in Table 2. Charge distribution and other relevant parameters are shown in Figure 6.

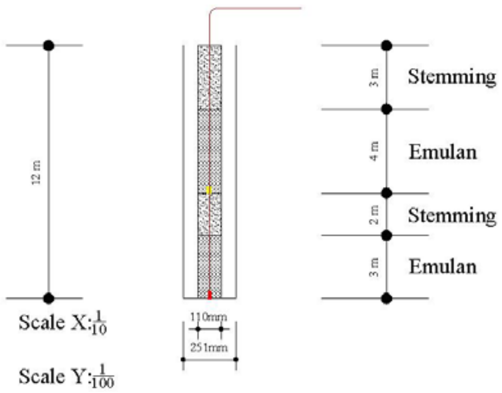

Figure 6: Charge distribution and pre-splitting parameter in the hole for test3

Number of holes in the pre-split row was four. The following results can be concluded carrying out these tests:

- A crack can be seen between the holes in the pre-split row but with a small aperture (Figure 7).
- In practice, using deck charging is very difficult and uncontrollable. For this reason, tests using continuous chagrins were planned.

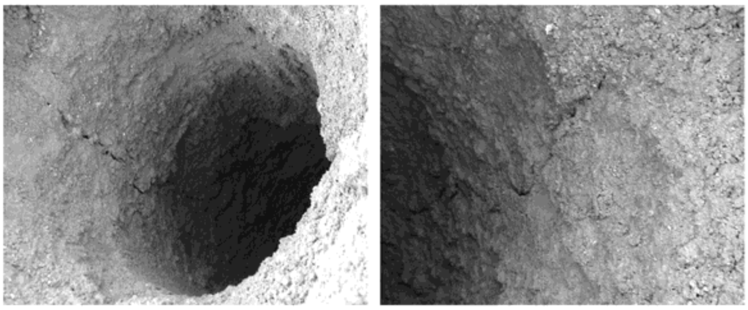

Figure 7: A view of cracks produced in test 3

6-2-Continuous charging

Five tests, four with pipe diameter of 90 mm and one with pipe diameter of 110 mm, using continuous charging were carried out. Regarding to dynamic tensile strength of rocks, applying Equations 2, 3 and 4, hole pressure in wet condition and charge length were estimated for each test. Pre-splitting parameters for all of the tests are given in Table 2.

In the second test in Table 2 (first test in continuous charging) charge length was 10.5 m and stemming was 1.5 m. In this test, the explosives were thrown out of the hole, caused probably by a low stemming. No crack was created between holes in the pre-split row (Figure 8).

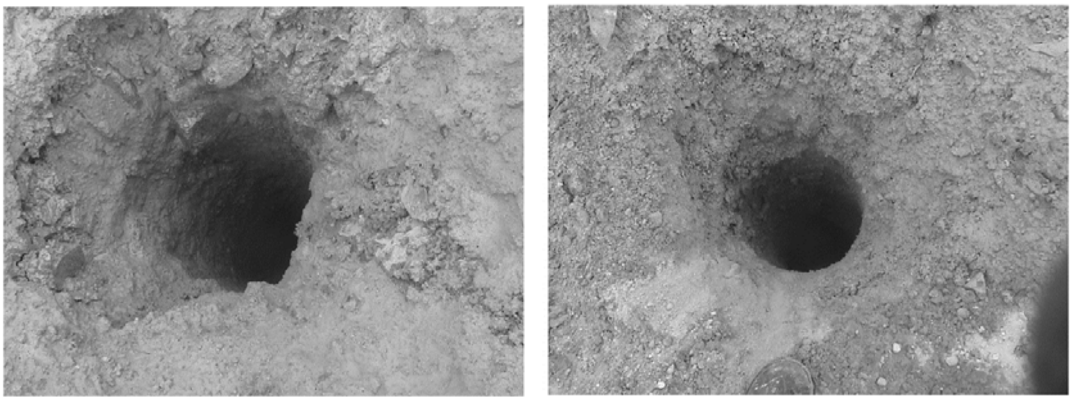

Figure 8: A view of results in test 2

In the third test, spacing was the same as the second and stemming was 2.5 m. Due to fallings, the holes were filled up and hole length was reduced to 7 m. Two Boosters of 1 lb (50 % PETN) were used in the bottom and the middle of hole. The results were creating cracks between holes. Also, back breaks were observed, likely caused by over charging in the top of holes.

In the test 4, the parameters were the same as previous test, only boosters of 1 lb in the top of hole was replaced by two 2 boosters of 1/3 lb. Excellent results were obtained. An opening of 4 cm between the holes was observed without no over break (Figure 9).

Figure 9 : Created opening in two sides of the same hole in test 4

Test 5 was carried out using the same parameters as in test 4 to confirm the results obtained in test 4. Satisfying results were also achieved in this test (Figure 10). Based on the results obtained, in case of continuous charging with pipes with diameter of 90 mm, the optimum parameters for pre-splitting are set as: stemming 2.5 m-3.5 m, spacing 3 m, 1 Booster of 1 lb in bottom and 2 Booster 1/3 lb in the middle of holes. The only problem was faced, was difficulty in charging the holes by Emulan truck (the pipe diameter was almost the same as the hose diameter of Emulan truck).

For this reason, a test was planned using pipes with diameter of 110 mm and parameters as in test 5. The results were creation of a band of parallel cracks between the holes with unwanted fragmentation in the top.

Figure 10: Results obtained in test 5

7-CONCLUSIONS

Satisfying results were obtained using pre-splitting method with large diameter holes, along with decoupling-continuous charging in Sarcheshmeh copper mine. It is concluded that:

- 3 m spacing between the holes in the pre-split row and 2.5m-3.5m of stemming deliver good results.
- In the large diameter holes, in wet condition, using bulk explosives, having a proper stemming, a minimum of 2 m is vital for obtaining acceptable results.

- For using bulk explosives in a wet condition, application of deck charging method is not recommended.
- In practice, in pre-splitting decoupling method, using bulk explosive in a wet condition is difficult and it is suggested to move to cartridge form of explosives.

ACKNOLEGMENTS

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Table 2: Pre-splitting parameters in the tests carried out

Test Number	Number of holes	Burden(m)	Spacing(m)	Type of charge	Pipe diameter(mm)	Hole Length (m)	Water level(m)	Lenght of charg(m)	Un axial Compressive Strength(MPa)	Tensile Strength(MPa)	Stemming (m)	Rock Density	Explosive			Quality
													Emulan(kg)	Booster (1 lb)	Booster (1/3 lb)	
1	5	15	4	Deck	110	12	9	7	68	3.5	3	2.78	70	4	8	Excellent
2	6	10	3	Continuous	90	11.9	4.7	10.5	125	7	1.5	2.55	70	8	0	Bad
3	6	10	3	Continuous	90	7.5	7	4.5	130	6.6	2.5	2.57	30	8	0	Good
4	6	10	3	Continuous	90	10.5	9	8	95	5.3	3.5	2.48	50	4	8	Excellent
5	6	10	3	Continuous	90	12.4	11.5	8.5	93	4.6	2.5	2.47	40	4	8	Good
6	6	21	3	Continuous	110	11.6	4.6	9	95	4.6	3	2.52	100	4	8	Intermediate