Efficient use of energy to control bench damage

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Abstract

The impact of a higher copper price on the open pit metal mining sector has derived in a faster and safer way in which the mining operation of broken and mineralised material is carried out. In this regard, a good control of bench stability allows a lesser extra removal of material and so more safety to get the planned ore. The stability is ensured through an efficient drilling and blasting, applying the current technology and available know-how. An efficient use of energy through low-density explosives which are the most adequate for the existing solid rock releasing energy in a smoother way through a deterministic detonation sequence which is the application experience presented here. This application experience has two main technological factors; the adequate type of explosive for the kind of rock, in terms of velocity of propagation (Vp) together with the use of a determined detonation sequence and the appropriate designs, which allow to reduce the level of damage to the walls and to maintain a minor backbreaking through quantification with vibration modelling carried out at the near field. The reductions achieved were 30% lower in peak particle velocity.
INTRODUCTION

The improvement and benefits resulting from the control and optimisation of the bench stability, is a topic that is not normally included in a mine annual budget and additionally it is an operational factor that tends to decrease the ore mining velocity at the mine. From the viewpoint of the Drilling and Blasting Area and from Geomechanics, bench stability is an additional expenditure due to extra material to be mined.

Clearly, this is an opportunity for improvement, and especially today due to higher mineral prices.

How to address this improvement opportunity? It is a process that begins by acknowledging the geological and geomechanical properties of the place and applying an adequate drilling and blasting design in order to mitigate this damage, backed up by vibration measurements in the near field and with quantitative evaluations of the back break. But, what happens when these changes do not derive in change or improvement at the open pit benches?

Well, in this point is where we must dig deeper in the quality of information obtained with respect to the solid rock we are going to blast and this could be through refraction seismic profiles that deliver relevant data such as the velocity of propagation, a proved indicator of the rock quality, very related to the type of explosive to be used. By knowing the relationship velocity of propagation versus velocity of detonation, we must research in the technology and know how the most appropriate solution to distribute the energy in the best way and have the most proper times, to achieve the objective which is bench stability control.

For the application of these new designs and the use of technology, the evaluation system used was vibration measurement at the near field (bench berm), applying the Holmberg and Persson model plus pre and post blasting Vp measurements (to know the damage suffered by the rock after each blast), and back break measurements.

This work describes a way to attain control and improve the stability by efficiently using the energy to control the damage by applying technology and technical know how. The area under observation corresponds to zones with soft and fractured rock, where pre split is not a solution.
BENCH DAMAGE ASSESSMENT

In the first stage of this work, we started assessing the base line in terms of vibrations results in the near field and back break at a bench levels, in the most critical sectors studied we saw the stability.

In current blasting it was used delay timing with Nonel system for benches of 15 m high and 311 mm drilling diameter.

Blasts associated to the base line were assessed with velocity of propagation measurement through seismic refraction in blasting, and pre - post blasting in the berm of the bench of that blasting. Besides, the peak particle velocity was measured and the model for the near field was obtained from the Holberm and Pearsson (H&P) modelling.

The advantage of applying the seismic refraction technique allows us to clearly see, how come and how much energy we must add to the solid rock we want to blast, in terms of velocity of detonation (VOD). In the figure N°1 (ref. 1, see last page) you can see in-depth an iso Velocity of propagation (Vp) profile of a pattern to blast. This type of in-depth information of the Vp, detects 15 m bench zones, where it is not necessary to arrive with energy (Vp < 1500 m/s). On the other hand, it indicates, as well, that the current explosive used for a 311 mm drilling diameter has an average VOD of 4500 m/s, which is very damaging for a solid rock to be blasted with a Vp between 2500 to 3000 m/s, since for this type of rock the maximum VOD to apply in explosives is lower than 3000 m/s (ref. 2, see last page).

With this restriction to control the efficient energy to the solid rock, there is a way to reduce the linear density of a charge in each hole, via a lower VOD and a smaller drilling diameter, but the latter one was not operationally possible, so the technology in the explosive allows us to employ low density emulsions, reducing such linear charge by each hole. Therefore, for this situation we apply low-density explosives, allowing a better distribution of the charge in the hole. This explosive has a lower VOD, between 2600 m/s and 3200 m/s depending on the hole diameter. This condition allows reducing the detonation pressure in the hole.
Under the same solid rock conditions (see figure N°2), details a halo of damage (ref. 3, see last page), red line, caused by the proposed charge configuration for a buffer row. It is used low density emulsion and air in the column. Graphic on the Figure N°3 shows as a comparison a simulation of the damage achieved by applying the charge configuration chosen for the designs of the base line, provoking damage at the bottom by excessive energy concentration. Likewise it highlights a better distribution of energy and a smaller area with damage.

In addition to the above mentioned, with the same rock data for the field and base line measurements, by an analysis of the damaging energy, by criteria of damage by tension (ref. 4, see last page) and the constants of the H&P modelling, we could simulate the changes in designs, which could help to reduce the damage to the next bench and crest. Taking into account the constants found in the H&P modelling with the data of the previous bench, different charge alternatives are simulated, using new drilling and blasting designs, with the adequate explosive for the type of rock.
In the figure N°4 the damage provoked to the slope is simulated, by applying the design of the current patterns. There you can appreciate that benches and berms are being damaged by an intense jointing (4 Vcrit.), but in the Figure N°5, by applying know how in the design and technology in the explosives, we can clearly see that the damage caused by tension in the rock is drastically reduced in the next bench, crest and berm zone.

Once defined the correct energy for the solid rock, distributed in the holes to blast, we analysed another relevant point which was the change in the initiation system; from a stochastic to a deterministic system, i.e., the systems with electronic initiation which allow in these cases a control in the damage provoked to the bench;
a) The accurate initiation on time in each hole, after obtaining the critical time of coupling, via the elementary waveform in a hole with buffer row.
b) The energy propagation is perpendicular to the berm being preserved, see Figure N°6.
c) Flexibility by initiating in the first place all holes from the last production row, and then initiating the rest of the production holes, sending the wave propagation in the spacing to the open pit.
d) Initiation of the buffer row with defined relief times, appropriate for the type of rock.

RESULTS

VIBRATION MONITORING

In the vibration models, using the H&P formula, we can see the reduction achieved by using the new designs, see Figure N° 7.

We must take into account that in order to reduce the damage to the slopes the following changes were carried out to the design of the baseline:
- The drilling moves away from the row of the program 2 m
- All blastholes rows move away from the slope to preserve
- The charges used in the buffer rows are reduced
- Use deterministic delay timing to ensure that each charge detonates on its time
- Use of the appropriate explosive energy to break the rock.
- The crest and berm of the next bench is protected with negative sub-drilling in buffered rows and in the last production row

Figure N°7

- Model with pyrotechnic detonators and old D&B designs
- Model with electronic detonators and new designs proposed for the next bench
It can be observed, benchmarking the different models, that we have a reduction in vibrations of approximately 25% to 30%.

**VISUAL RESULTS AT THE BENCH AND BACKBREAK**

It is observed a better slope respect back break and stability. We do not have over-digging or formation of overhangs, obtaining a stable and safe slope.

- The low-density explosive used has slower velocity of detonation than the commonly used Anfo. This slower velocity of detonation causes less detonation pressure in the hole, better distribution in the column, and a reduction in the linear powder factor. Necessary conditions to reduce the damage to the slopes in the Mine.

- By doing a statistical comparison of values between current crest and designed crest, we have as a result a back break of 5.0 m. By observing the pictures we realise we have an stable and well achieved slope.
CONCLUSIONS

• When the bench stability becomes a serious issue in zones with fractured and soft rocks, it is important to know the Vp profiles of the zone to blast, in order to select the adequate distribution and explosive with a VOD, at the most, the same as the Vp

• Presplitting is not an efficient alternative for this rock condition.

• The mix in the know how and technology, expressed in the Vp profiles, low density emulsion and deterministic detonation times, allow us to efficiently use the energy to control bench damage. This is echoed in measurements of;
  
  ➢ Vibrations and damage modelling, showing a reduction in the damage at a berm level between 25% and 30%.
  ➢ Vibration modelling, allows simulating the damage associated to the proposed design, the intense jointing is eliminated and the creation of new joints is reduced in 50%.
  ➢ The back break, at a crest level, was reduced from 18 m to 5 m.

• The advantage of this new detonation sequence is to allow the initiation of a production blasting in just one event, with a controlled blast in the slope. This allows not altering the mine production rhythms in the blasting controlled zones.

• It is obvious that the application of these new buffer blast designs can continue reducing the levels of bench damage, replacing the current drilling diameter with a 165 mm drilling diameter

• As an additional benefit with these new drilling and blasting designs, the drilling and blasting costs were reduced in 3.2%
References


Ref. 2: F. Chiappetta, 2005, Technical Workshop to OMS.
