11th International Symposium on Rock Fragmentation by Blasting

Paper Number: 154

Optimisation of Drill and Blast for Mill throughput Improvement at Ban Houayxai Mine

J. Gaunt[1], D Symonds[1] G. McNamara[1], B. Adiyansyah[1], L. Kennelly[2], E.J. Sellers[2] and S. S. Kanchibotla[2]

[1]Ban Houayxai Operations, Phu Bia Mining Ltd and [2]JK Tech

ABSTRACT

Ban Houayxai is a gold-silver mine owned by PanAust Limited (an Australian Securities Exchange-listed company) and operated by PanAust's 90 per cent-owned subsidiary Lao-registered company, Phu Bia Mining Limited (the Government of Laos owns the remaining 10 per cent) in Laos since 2012. The first two years of operation has processed predominately soft oxidised ore but subsequent years were expected to process more fresh hard ore. Fragmentation from fresh primary hard ores was also expected to be much coarser than the soft oxide ores. This coarser and harder ore to the mill is expected to have a significant downside to mill throughput and mining productivity. The Ban Houayxai management realised the potential downside risk from fresh harder ores and implemented a blast optimisation project to deliver finer fresh ore to mill without unduly increasing blast induced dilution and damage.

JKTech and Ban Houayxai drill and blast team implemented a joint blast optimisation project since April 2013 to achieve finer fragmentation from fresh ores. This was achieved by modifying the bench geometry, blast patterns and exceptionally high levels of quality control during implementation. Blast induced ore loss and dilution was controlled by adjusting the ore blocks for blast movement. Finer fragmentation from these modified designs exceeded the design mill throughput for the hard fresh ore by 46% on average. These new practices have been embedded in site operating procedures and by providing quick reference "cookbook" document for the engineers.

INTRODUCTION

Ban Houayxai is a gold-silver mine owned by PanAust Limited (an Australian Securities Exchange-listed company) and operated by PanAust's 90 per cent-owned subsidiary Lao-registered company, Phu Bia Mining Limited (the Government of Laos owns the remaining 10 per cent) in Laos since 2012. The first two years of operation has processed predominately soft oxidised ore but subsequent years were expected to process more fresh hard ore. Fragmentation from fresh primary hard ores was also expected to be much coarser than the soft oxide ores. The feasibility design throughput of the mill with hard primary ores was assumed to be around 400 tph compared to 700 tph with oxide ore. Figure 1 below is a snapshot of throughput changes in the SAG mill while feeding the fresh hard ore. It can be clearly seen that mill throughput has dropped from approximately 700 tph when processing oxide ore to almost 300 tph when processing hard primary ore. This drop in throughput with primary ores is more than what was predicted in the feasibility designs and it posed a significant business risk the operations.

In addition to the throughput reduction, the coarse fragmentation also posed significant maintenance risks to machinery, storage bins and conveyors (due to high transfer drops). Since there is no stockpile between the primary crusher and mill, any changes in the feed characteristics also lead to wide fluctuations in mill performance and did not provide enough time for the mill operators to adjust the mill operating conditions. Therefore feeding the mill with finer and consistent ore characteristics is considered to be critical to maintain consistent mill throughput.

Drilling and blasting is the first step in the comminution and separation process and plays a major role in providing consistent and finer feed to the mill (Kanchibotla, 2000). The energy and cost of drill and blast is relatively less compared to the crushing and grinding breakage downstream (Kanchibotla, 2013), hence there is an opportunity to utilise the explosive energy to provide a finer and consistent feed to the mill. Similarly by understanding blast movement dynamics, it is possible to minimise ore loss and dilution risk and provide consistent feed grade to the mill.

Ban Houayxai management realised the leverage of drill and blast operations to minimise the risks from hard fresh ores. They engaged JKTech to implement a joint project with the mine drill and blast team to achieve finer blast fragmentation from fresh ores by modifying the bench geometry, blast patterns and exceptionally high levels of quality control during implementation. Blast induced ore loss and dilution was controlled by adjusting the ore blocks for blast movement. This project was implemented by implementing a series of carefully monitored blast trials to characterise the changes in a step by step approach.

GEOLOGICAL AND GEOTECHNICAL SETTING

The Ban Houayxai deposit is a narrow vein, structurally controlled gold-silver deposit located in the north of the Lao People’s Democratic Republic. Mineralised veins are predominantly hosted within intermediate volcanic rocks which have been subject to green schist facies metamorphism and structurally juxtaposed against a siliciclastic package of probable lower metamorphic grade. Pit slopes are predominantly controlled by geological structures from at least five geological events (King, 2014). Localised failure potential is dependent on the orientation and inter-relationships of the various defects as wells as the shear strengths which can be mobilized on defect surfaces. There are seven geotechnical design sectors classified according to similarities of geotechnical strength and slope components.

The multiple sequence of faulting events has led to a high degree of variability in the rock strength due to varying degrees of alteration. The rock tends to have an anisotropic fabric and the point load strengths are related more to fabric angle than to intrinsic strength. Point load tests data indicates that there is a general trend to increasing strength with less alteration (Figure 2).

BENCH GEOMETRY AND ITS IMPACT ON FRAGMENTATION

Prior to implementation of the optimisation project, drill and blast operations at Ban Houayxai were conducted in 5m benches and mined in three flitches - bottom flitch, middle flitch and top/ heave flitch. Fragmentation measurements from photographic analysis indicated that blast designs from the current bench configuration produced coarser fragmentation in the transition and fresh primary ores (Figure 3).

One of the main reasons for coarse fragmentation was due to poor energy distribution from 5m bench blasts. An energy distribution analysis of 5m benches showed that about 44% of the bench had very little explosive energy hence is likely to produce coarse fragmentation especially in top / heave flitch. Therefore the first stage of optimisation was to improve the explosive energy distribution by increasing the bench height to 10m (Figure 4).

STAGE 1: BLASTING TRIALS WITH 5M AND 10M BENCHES

Blasting trials were conducted over two weeks starting mid-October 2013. The location of the trial blasts and their designs are shown in Figure 5. The trial blasts with 5m and 10m benches were located side by side to minimise any geological variations. The strength and structural characteristics of 5m and 10m blocks are similar as per point load index and fracture frequency data from the block model (Figure 6). Blast parameters are shown in Table 1.

During the trials, the site blast crew implemented the designs with excellent quality control. Blast hole depths were measured and the median depth for all holes was within 25mm of the design depth, which was considered to be very good. Video analysis of the blasts indicated some cratering at the initiation point and along the control row but minimal cratering in the body of the blasts. This indicates that confinement is generally adequate due to constant stem height resulting from the consistent hole depths and explosive charging.

Fragmentation of muckpiles was measured using the SPLIT photographic method. Ore from each flitch was campaigned through the mill for a minimum of 24 hrs and belt cuts were taken from primary crusher product and sieved to estimate feed size distribution. Fragmentation analysis from muckpile photos showed little difference in 5m and 10m benches but sieving results from the belt cuts indicated significantly more fines (P20) in 10m bench blasts compared to 5m bench blasts (Figure 7). One of the reasons for not showing any difference in muckpile fragmentation is because of the inability of image analysis techniques to accurately estimate fines.

A comparison of mill performance from each flitch from these blasts clearly showed the influence of finer fragmentation on mill throughput (Figure 8). On average, ore from bottom flitches resulted in higher throughput compared to heave flitches and 10m bench blasts resulted in higher throughput than 5m benches. Since 10m benches have more ore from lower flitches, on a weighted average they resulted in almost 24% more throughput than the ore from 5m bench blasts.

STAGE 2: HIGH ENERGY BLASTING TRIALS

The higher benches were continued but early in 2014, harder primary ore was exposed much sooner than anticipated and caused coarser fragmentation and lower throughput rates, especially from the heave flitches. This led to the trialling of high energy blasts to mitigate the impact of hard primary ore on plant throughput. A trial blast program with higher blast energies was implemented in March 2014. Blast design comparison from stage 1 and stage 2 trials is shown in Table 1. All the trial blasts in stage 2 were carefully monitored and the ore was campaigned through the mill to quantify the impact of higher blast energy.

Fragmentation estimates from image analysis of muckpile photos indicate finer fragmentation from stage 2 high energy blasts compared to 5m and 10m trial blasts from stage 1, especially in heave flitches (Figure 9).

The mill throughput was monitored over the total time to dig the three high energy trial blasts. Figure 10 shows the median throughputs for each of the trial blasts divided by flitch. As expected the heave flitches resulted in lower throughput compared to lower flitches. However, blast 117 with smaller diameter blast holes (127mm compared to 152mm) resulted in more uniform fragmentation and throughput from all flitches compared to the other two trial blasts. The heave and top flitches of blast 116 was noticeably lower because of poor confinement from the free face conditions on two sides. Overall, median throughput from the high energy trial blasts was 621tph, which is significantly higher than the design throughputs of 500 tph and 400 tph for transition and primary ores respectively. Comparison of mill throughputs from stage 1 and 2 was considered to be inappropriate because the mill operating conditions in stage 2 were different to stage 1. In stage 2, the mill was running under restricted operating conditions due to worn liners and bogging of downstream leach tanks.

DILUTION AND DAMAGE

It must be recognised that there will always be movement and damage associated with blasting but the low energy blasts with shallow benches lead to considerable oversize that compromises plant throughput. The general mining industry perception is that increased blasting intensity will increase the risk of blast damage, un-controlled blast movement hence ore loss and dilution. In operations where the dilution and damage are critical issues, blasts are usually designed with low blast energies often leading to poor production efficiencies.

An alternative approach to manage blast induced dilution is to understand the blast movement dynamics from comprehensive blast monitoring and modelling and adjust the ore blocks to compensate for blast movement (Rogers and Kanchibotla 2013). This approach was applied successfully at a large gold operation in Ghana (Engman et al 2012). A similar dilution management plan was implemented at Ban Houayxai. All the trial blasts from stage 1 and stage 2 were monitored using the blast movement monitors and the resulting blast movements for each flitch are shown in Figure 11. Using the measurements, templates were developed for each flitch and blast configuration to minimise adverse ore movements and then adjust the ore blocks for blast movement.

One other consequence of high energy blasts is the tendency to activate faults and cause damage to the nearby walls. To prevent the activation of joints into the wall, and reduce the damage behind the high energy blasts, it was decided to use the concept of an active split between the production and trim shots and then to limit the energy in the trim shots. As a general rule, the split should be fired prior to the production blast to limit structure activation. The results of a trial split are shown in Figure 12. The active split was definitely effective in reducing joint activation from the high energy production blast and only minor joint activation was mapped. The crucial issue for maintaining geotechnical stability is not to activate these further during the trim blast. This paper does not cover the full details of the blast movement and damage study which will be published in future.

IMPLEMENTATION QUALITY AND SUSTAINING THE CHANGE

The fundamentals for successful implementation of drill and blast improvements were, in this case, achieved through developing a respectful interpersonal relationship amongst the drill and blast crews. This proved in time to have a flow on effect throughout the section resulting in drill and blast operations becoming a combined entity, cognisant of each function's contribution to the overall result. Firstly, individuals that showed signs of striving to better themselves were encouraged to progress through training programs that achieved competency in their role in "drill or blast". This progression was seen to build confidence within the individual and gave them a purpose and worth amongst the remainder of the team. This respectful and self-promoted hierarchy structure then enabled positive learnings to be populated throughout the section in a sustainable manner using local dialect and in keeping with cultural values. Secondly, consistency in delivering achievable outcomes that were production orientated within a timely fashion evolved into an infectious "Can Do" attitude amongst the drill and blast section. This promoted the section as unique and available for challenge under an ever increasing production based value chain where safety was at the forefront. Deliverables within the section were now perceived as non-negotiable, highlighting even further the stringent safety elements that were the key underlying factors during the competency training programs "now part of everyday life" as routine.

Linking the aforementioned was attention to detail in the form of drill and blast QAQC under a specialist team within the section. This regimental QAQC process validated what could be interpreted as a pre-blast evaluation report that could be replicated within similar geological conditions as required.

The blast master concept was implemented to link the geology, grade control and geotechnical hazard mapping. Previously, a diligent blast by blast assessment by the geotechnical section did not provide the drill and blast team with timeous information that they could understand. The development of blastability indices for the mine based on the block model (Jackson et al, 2014) enabled the prediction of the rock blastability and the estimation of the powder factor to achieve a given fragmentation size. A procedure was developed to integrate this block model with an assessment of every blast on the next level to be blasted. The structural map is superimposed to identify which production blasts are likely to activate faults into the final walls. These activations can be prevented by active splitting. After the trim blasts have been excavated an on-site post blast assessment is led by the geotechnical section with the geologist, drill and blast and mine planning engineers present to identify future hazards and provide learning for the team.

To sustain the change, a cookbook of operational procedures was developed. This provides the team on site with a set of design guidelines for the various blasting types and domains. In addition, the procedures for grade control and mining operations are defined and linked with pictures to illustrate correct implementation. In addition more detailed information on procedures is supplied as a reference for the reasons behind these implementation methodologies and to assist with training of new engineers.

CONCLUSIONS

A drill and blast optimisation project with a view to improve mill throughput was implemented through systematic trials and comprehensive blast and plant monitoring. High quality blast implementation allowed the influence of the blast design changes to be observed directly and not confused by typical variations in implementation quality. The project demonstrated that the use of higher benches and significantly increased blast energy decreased fragmentation size, reduced costs, maximised mill throughput and improved profitability of the overall value chain.

This approach confirmed that the higher powder factors resulted in finer fragmentation and led to mining efficiencies and mill throughput that exceeded design expectations for the hard fresh ore by 46% on average. The trials provided validation that smaller diameter holes produce more uniform fragmentation through the muck pile, though at the cost of much more drilling.

It must be recognised that there will always be movement and damage associated with blasting but the low energy blasts with shallow benches lead to considerable oversize that compromises plant throughput. An alternative approach is to comprehensively monitor and understand blast movements and implement a plan to minimise adverse blast movement and then adjust ore blocks for blast movement. Similarly understand the mechanisms for blast damage from careful monitoring and then develop techniques to minimise damage. One such technique is the use of active split to minimise the activation of structure from high energy blasts.

The project illustrates the dual benefits of removing drill and blast design constraints and focus on implementation quality to create significant value to a small, low grade operation. These benefits have been sustained by team integration and the development of a cookbook as a reference document.

ACKNOWLEDGEMENTS

The authors acknowledge the contributions from all the personnel on site who worked meticulously to achieve the project objectives. They are grateful for the support of PanAust and Phu Bia Mining and their permission to publish this work.

REFERENCES

Engmann, E., Ako, S., Bisiaux, B., Rogers, W., and Kanchibotla, S. (2012), "Measurement and Modelling of blast movement to reduce ore loss & dilution at Ahafo Gold Mine in Ghana", Proceedings of the 2nd UMaT Biennial International Mining & Mineral Conference - UBIMMC., Tarkwa, Ghana.

Jackson, J., Gaunt, G., Astorga, M. (2014) Predicting mill ore feed variability using integrated geotechnical/ geometallurgical models. Orebody Modelling and strategic mine planning symposium 2014. Perth, W.A. 24-26 November 2014. Dimitrakopolous, R. (ed), AUSIMM. 165-175.

Kanchibotla SS, (2000) Mine to Mill Blasting to Maximise the Profitability of Mineral Industry Operations. Proc. 26th Annual Conf. on Explosives and Blasting Technique, Anahiem.

Kanchibotla, SS (2013), Mine to Mill Value Chain Optimization – Role of Blasting. SME 2013, Denver USA.

King, S. (2014) Structural Geology of the Ban Houayxai Au-Ag Deposit, Laos: Proposal of Work to Review the 3D Fault Models for the project in Relation to Open Pit Stability Modelling and Ore Controls. Solid Geology.

Rogers, W. and Kanchibotla S. (2013), Application of stochastic approach to predict blast movement. Rock Fragmentation by Blasting: Fragblast 10. P. K. Singh, A. Sinha (eds). CRC Press.

FIGURE CAPTIONS

Insert image (Use 'Image style')

FIG 1 – All figure captions should be listed together here. (Use 'Body Text' style)

FIG 2 – Caption here....

Figure 1. Impact of hard primary ore on SAG mill throughput

Figure 2 Relationship between point load strength I50 and alteration

Figure 3 Fragmentation from oxide, transition and primary ores

Figure 4. Explosive energy distribution in 5m and 10m Benches

Figure 5. Trial blasts layout

Figure 6. Strength and structural characteristics of ore in 5m and 10m trial blasts

Figure 7. Size distribution from primary crusher product belt cuts

Figure 8 Mill throughputs for different flitches from 5m and 10m bench blasts

Figure 9 Fragmentation for heave and bottom flitches FROM STAGE 1 AND 2

Figure 10 Median throughputs by flitch for the high energy trials

Figure 11. Measured blast movements from blasting trials from stage 1 and stage 2

Figure 12. Active split trials and results

TABLE CAPTIONS

TABLE 1 Trial blast designs details from stage 1 and stage 2

FIGURES

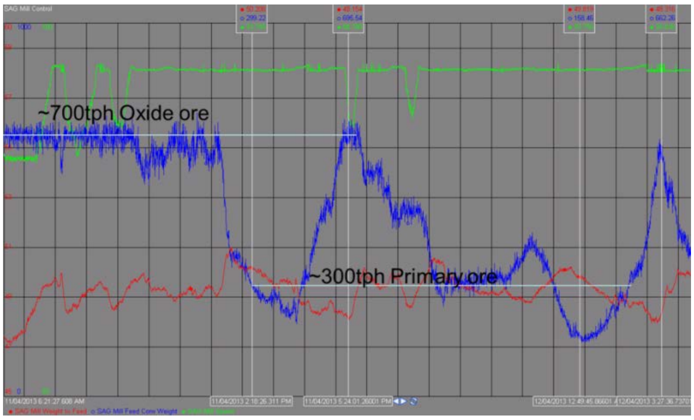

Figure 1. Impact of hard primary ore on SAG mill throughput

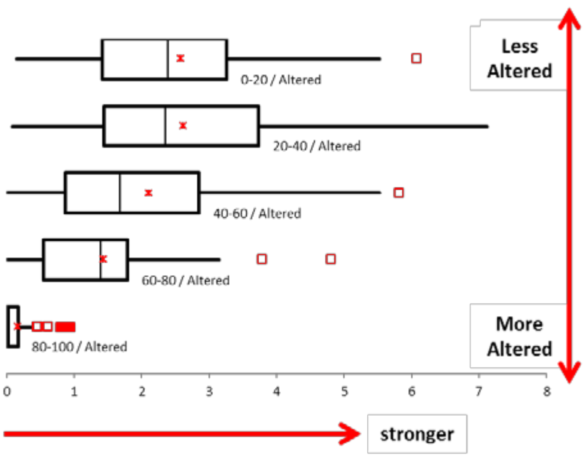

Figure 2 Relationship between point load strength I50 and alteration

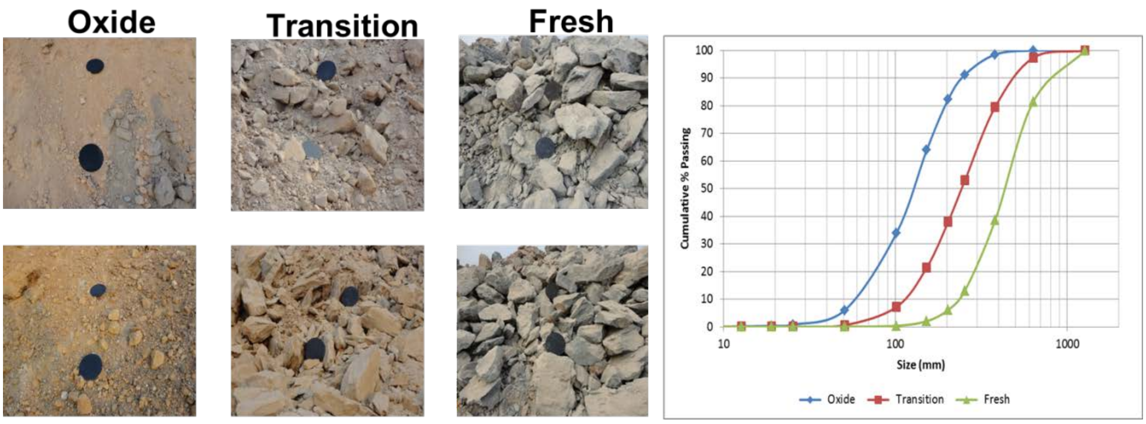

Figure 3 Fragmentation from oxide, transition and primary ores

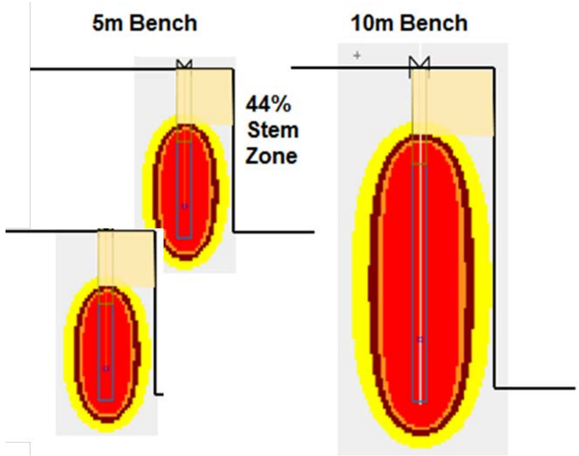

Figure 4. Explosive energy distribution in 5m and 10m Benches

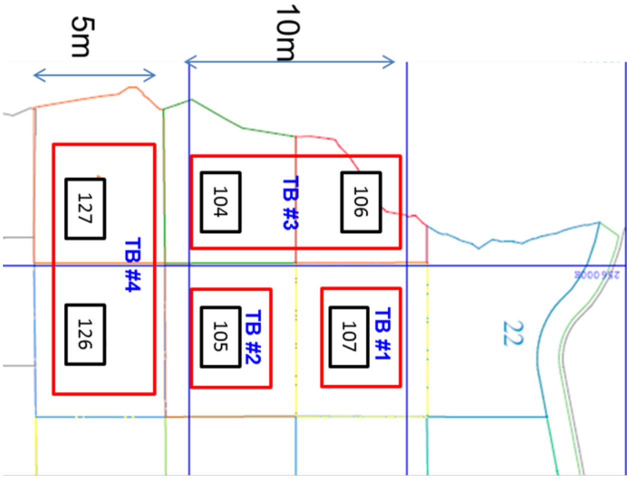

Figure 5. Trial blasts layout

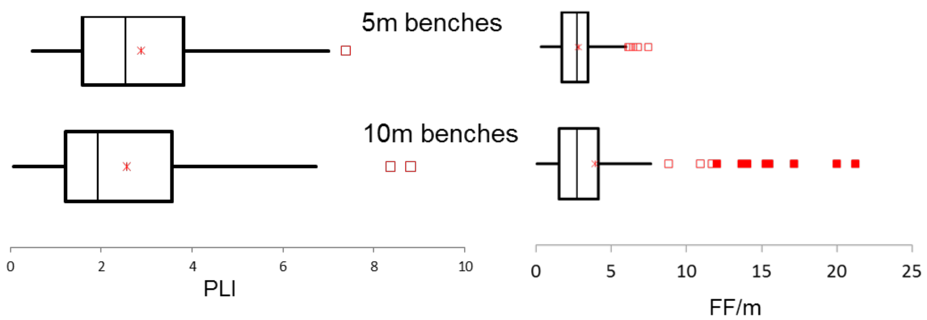

Figure 6. Strength and structural characteristics of ore in 5m and 10m trial blasts

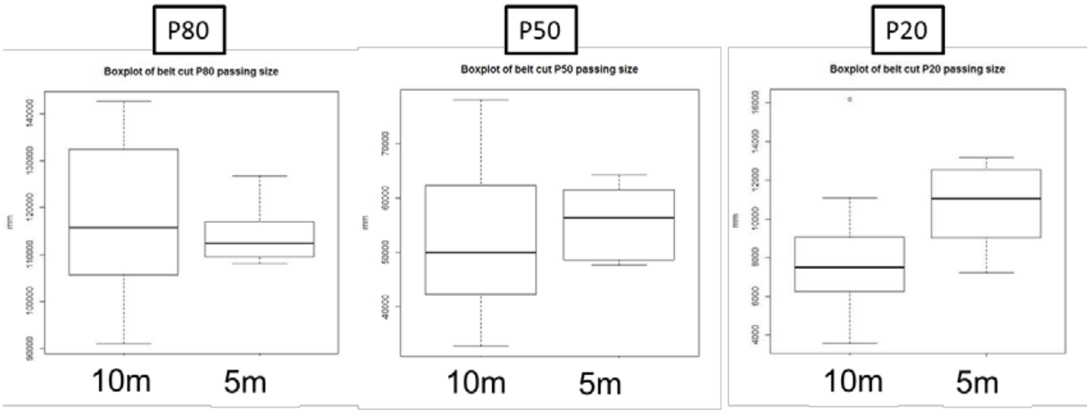

Figure 7. Size distribution from primary crusher product belt cuts

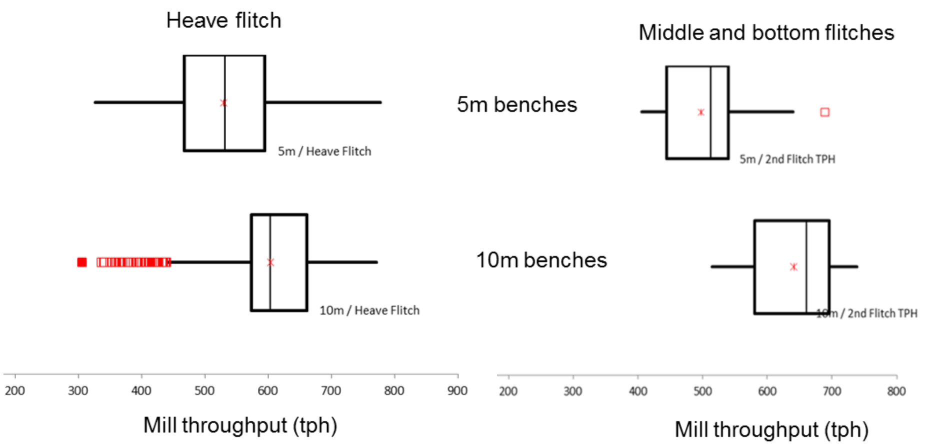

Figure 8 Mill throughputs for different flitches from 5m and 10m bench blasts

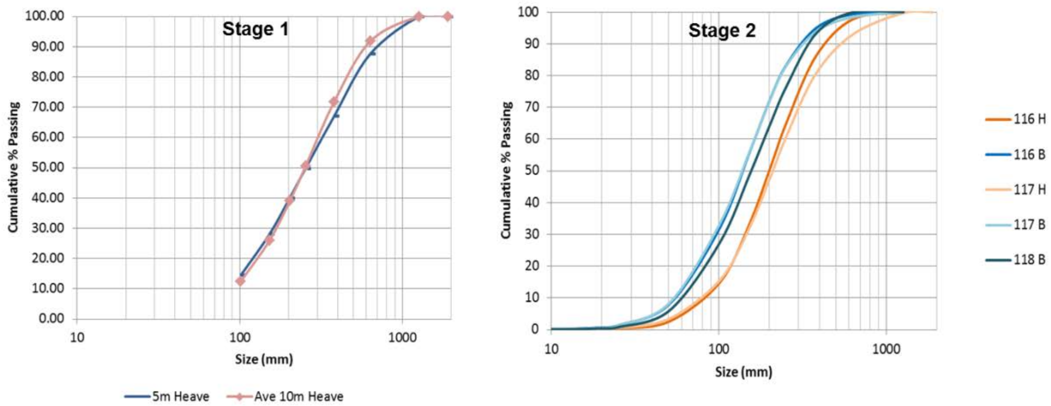

Figure 9 Fragmentation for heave and bottom flitches FROM STAGE 1 AND 2

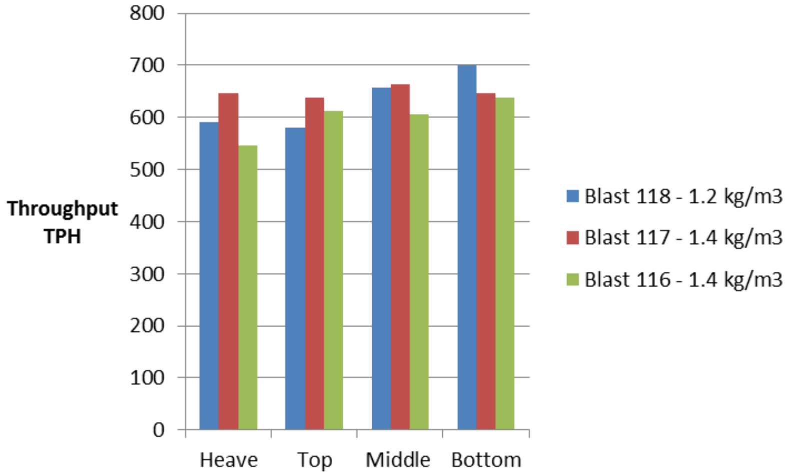

Figure 10 Median throughputs by flitch for the high energy trials

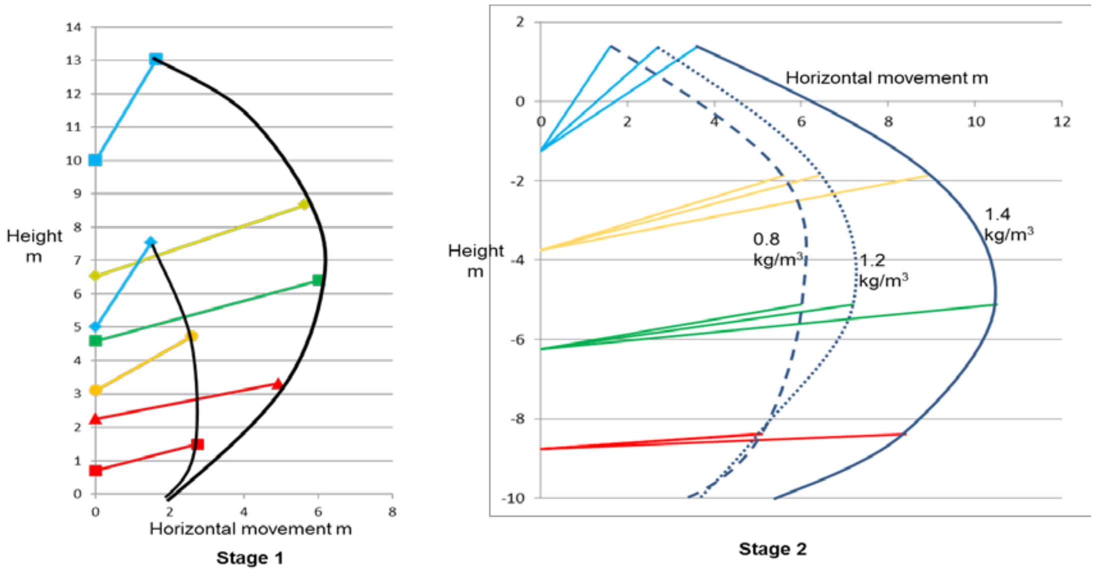

Figure 11. Measured blast movements from blasting trials from stage 1 and stage 2

a) Active split

a) Face behind active split

Figure 12. Active split trials and results

TABLES

TABLE 1 Trial blast designs details from stage 1 and stage 2

		Stage 1						Stage 2		
Parameter	Unit	Blast 126	Blast 127	Blast 104	Blast 105	Blast 106	Blast 107	Blast 118	Blast 116	Blast 117
Hole Diameter	mm	102	102	152	152	152	152	152	152	127
Bench Height	m	5	5	10	10	10	10	10	10	10
Burden	m	2.8	2.8	4.2	4.2	4.2	4.2	3.5	3.3	2.8
Spacing	m	3.3	3.3	4.8	4.8	4.8	4.8	4.0	3.8	3.2
Subdrill	m	1	1	1	1	1	1	1.0	1.5	1.0
Stemming	m	2.2	2.2	3.3	3.3	3.3	3.3	3.2	3.0	2.6
Powder Factor	Kg/m^3	0.8	0.8	0.8	0.8	0.8	0.8	1.2	1.4	1.4