Drill and Blast Optimisation at an Underground Copper-Gold Mine

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Abstract The process of utilising drill and blast techniques is used to improve mining performance. Drill and blast techniques have been proven to be more efficient and cost-effective compared to conventional mechanical rock breakage with machines. The degree of efficiency of the drill and blast process varies from mine to mine. These influencing factors result in drill and blast patterns that cannot be directly transposed from site to site meaning specific plans need to be developed. When creating new blast plans, unless they are created flawlessly the first-time revision or optimisation is necessary to ensure they are as efficient and effective as possible. The drill and blast patterns can be optimised to reduce the overbreak. A site specifically the current development is mining in both a weaker fragmented shale as well as moving down into a more competent granite. The optimisation will be considered for both types of ground but will have a stronger focus moving into the granite as the mine is approaching the first ore drives which are within the granite rock mass.

1 Background

The underground Copper–Gold Mine is located in South Australia. The mine is the Gawler Craton, which is known as an Archaean to the Mesoproterozoic crystalline basement. It was formed anywhere from 1450 to 3400 Ma years ago and covers around 440,000 square kilometres [1]. The mine is of iron oxide-copper-gold (IOCG) ore deposit. The ore body is cylindrical and extends around 1500 m below the surface and spans approximately 300 m in diameter, overlying the deposit is 470 m of Start Shelf sediment overburden. To extract the ore a sublevel cave/block cave mining method has been planned due to the nature of the ground ability to naturally fracture and subsid to where it will be extracted from the draw points. In the current stage of the mine development, the overbreak has been too high in the shale ground and

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the outcome has been identified to reduce it to less than 15% moving forward into the granite lower in the mine. Moving into the ore body it is expected to see an improvement in the competency of the rock due to the transition into a hematite rich granite giving it a higher density, therefore there should be a reduction in overbreak.

Overbreak, a result of the drill and blast procedure, is inevitable due to uncontrollable factors such as geotechnical and rock properties as supported by [3–6]. Any extracted material that is outside the planned profile is considered to be over broken and puts the risk on both workers and equipment [4]. As observed in the mine, a large amount of material was dislodged during scaling.

Blasting parameters causing excess ground vibrations have a large impact on the severity of overbreak. When PPV is reduced, it directly relates to the amount of energy released during the blast [7]. Factors that have been explored commonly in drill and blast systems include how the face is charged, for example, the notion of decoupling [3]. Decoupling is the practice of leaving the blast hole partially empty, so the explosive does not occupy the entire diameter. The purpose of this is that as there is a medium between the explosive and surrounding rock, the blast energy transferred to the rock is reduced due to having travelled through the medium. The opposite is a coupled hole, where the explosive occupies the entire diameter of the hole. If decoupling the perimeter holes is the answer to the overbreak issue, why isn't it utilised more often? The decoupling notion is possible with pumped bulk emulsion which could make it a potential factor for the excessive overbreak at the mine [3].

The opportunity to optimise the drill pattern is due to the ability of the Sandvik DD422i jumbo to communicate with a computer on the surface. Initially, a drill pattern can be created by using an engineering previous knowledge in the process of underground drill and blast and basing the pattern of similar size headings already active in that mine. Once the plan has been created it is uploaded to the drill rig where it is stored on the system. Once the rig has drilled a face the DD422i can collect, collate and condense data to produce information that is then able to be analysed. The key advantage of this system is the ability to analyse the data remotely from a computer located on the surface.

This process of data transfer between the drill rig and a computer located on the surface allows the chance to optimise the drill plans by viewing the outcome and making changes following the results of the blast. Linked directly to the jumbo is the program called Isure, developed for use with Sandvik machines such as the DD422i boring jumbo. Isure is utilised to create drill plans and process the data from the drill rig to display viewable information such as total drill metres, penetration rates and three-dimensional images. The two-dimensional image displays the planned drill holes superimposed against the actual drill holes carried out at the face. The three-dimensional image shows a computer-generated surface recorded from where the jumbo collared the holes.

2 Data Collection

To identify the current overbreak value, three cuts were made with the DD422i jumbo used to compare the drill pattern used against a slice of the drive from Deswik. The cross-sectional area can be compared to identify the overbreak.

2.1 Planned Drill Pattern for 4580 ACC-200

The section between the chainage values of 11.5 and 20.5 m doesn't contain any turnouts or stripping. Due to these characteristics, it is suitable to use this section as a control measure as there were no modified drill patterns used during the drill and blast process (Fig. 1b). Three-dimensional modelling is utilised using Isure to view a theoretical scale image of the drill pattern that will look once drilled (Fig. 1a).

The layout consists of the chosen drill pattern for three cuts. Fig. 2a presents the planned profile against the resultant profile for each cut. The blue dots are indicating the planned holes and the red dots are the holes after drilling, each cut has a round length of 4.6 m. Fig. 2b illustrates the planned profile design superimposed against the resultant drive profile showing evidence of both over break and under the break.

A key feature of the Isure program is the three-dimensional imagines (Fig. 3). These images illustrate the face upon drilling and how it should look after firing. Additionally, it highlights protrusions in the face, concaving or convex.

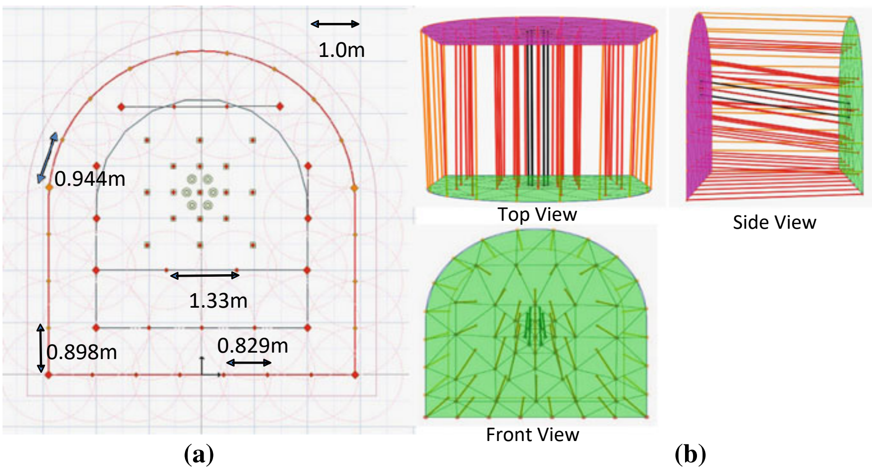


Fig. 1 **(a)** The drill pattern that was uploaded to the DD422i jumbo (T_5.8 × 6.2_1in25down), the theoretical drill pattern that should have been used. **(b)** Three-dimensional modelling (top, side and front view). The green surface represents the face profile surface area and the purple represent the bottom profile surface area

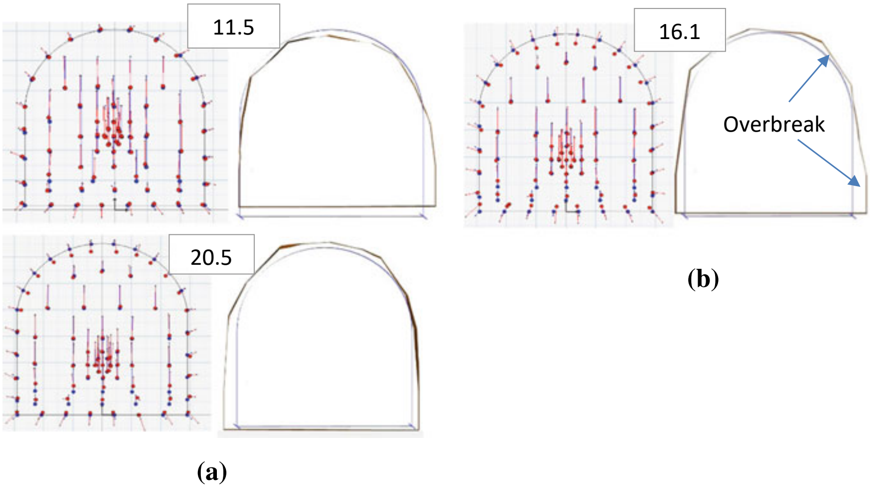


Fig. 2 Chainage 11.5, 16.1 and 20.5 m slice from Deswik (**a**); chainage drilled pattern (**b**)

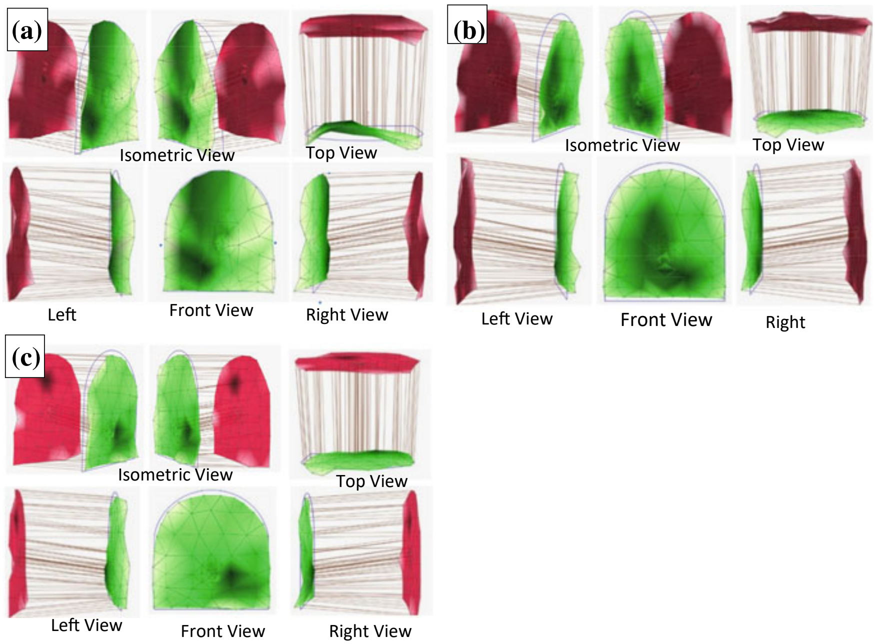


Fig. 3 Three-dimensional images: cut 1, (**a**) chainage 11.5 m; (**b**) cut 2, chainage 16.1 m; **c** cut 3, chainage 20.5 m. The green and red surfaces are the faces and bottom profile surfaces areas respectively

2.2 4580-ESD-001 New 51 mm drill plan—G_5.0 × 5.0_51bit Chainage: 37.3 m

The first trial was conducted at the chainage 37.3 m (Fig. 4). The major difference with this trial was the implementation of the 51 mm drill bits.

The drill plan results in the formation of large fragmentation (Fig. 5), which is undesirable because can have several implications relating to loading, hauling and processing.

Collars are defined as the drill hole on the initial face surface when boring a cut. The collars remain in the shoulder/backs on the right-hand side, this was due to not having a sufficient number of perimeter holes. Although the results indicated a lack of perimeter holes and it can also be seen there are a few exposed half barrels.

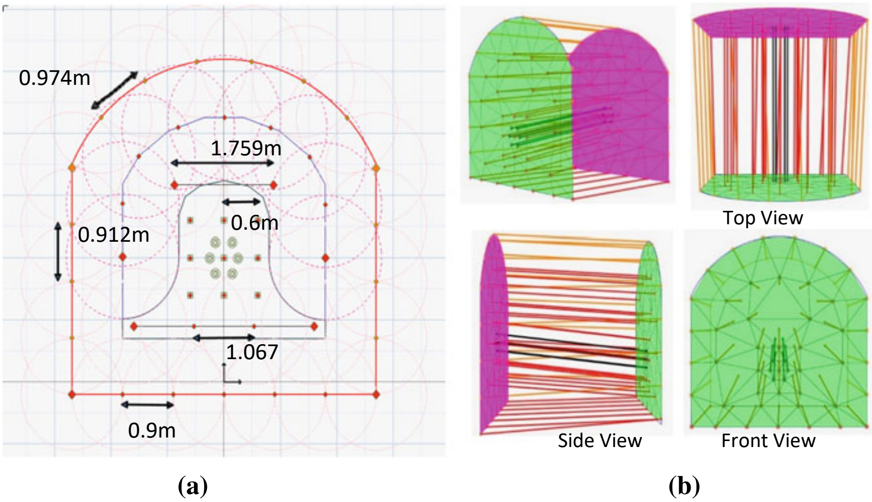


Fig. 4 **(a)** First adjustment and reduction in drill holes 51 mm drill trial. **(b)** Three-dimensional modelling (top, side and front views), 37.3 m drill plan

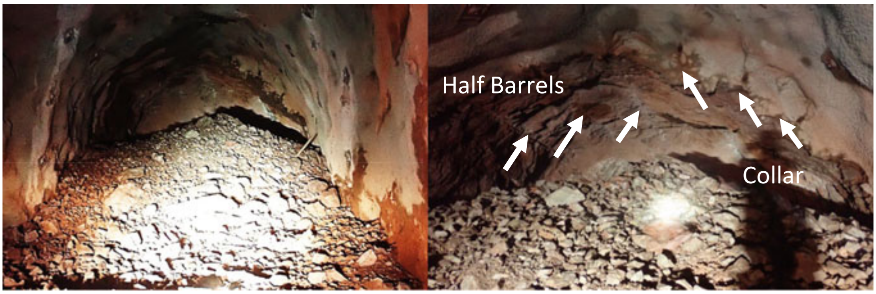


Fig. 5 ESD 001 first trial (4580-ESD-001 new 51 mm drill plan—G_5.0 × 5.0_51 bit, chainage 37.3 m)

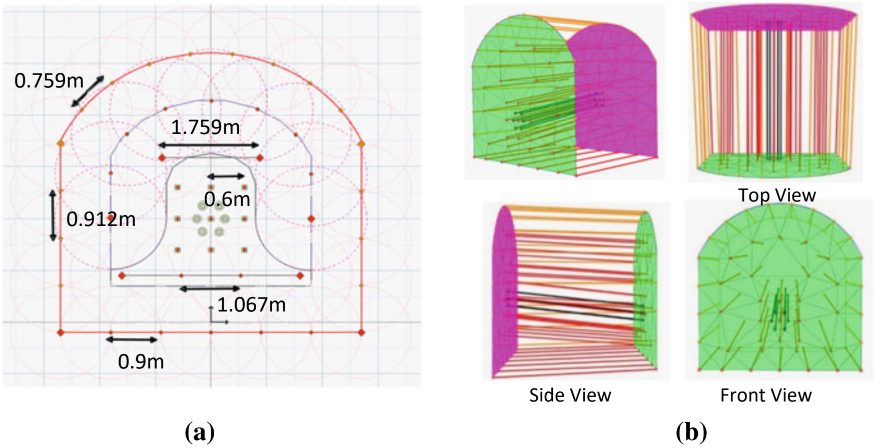


Fig. 6 **(a)** ESD 001 second trial (revised drill pattern, 51 mm bit, chainage 42.8 m) **(b)** Three-dimensional modelling (top, side and front views), 42.8 m

Half barrels indicate that the force from the perimeter hole explosion is directed in the intended direction. An ideal blast would leave half barrels around the entirety of the perimeter, shaping it to the desired profile. The version 2 design—G_5.0 × 5.0_51 bit_v2 was created as the second trial (Fig. 6a).

Adjustments were made due to the left shoulder/back having the collars present after blasting. To combat this the spacing of the perimeter holes was changed to 0.8 m, this allowed for the addition of two extra holes. The back holes were identified as wall contour perimeters holes not roof contour perimeter holes. Figure 6 gives the properties that this drill pattern has with explosive mass and drill parameters.

The inspection of the second trial (4580 ESD 001) displayed that the addition of perimeter holes mitigated substantial collars left in the face profile surface (Fig. 7). There were two shallow collars, one in the shotcrete and one in the left-hand shoulder, it would be possible to scale it out. Good fragmentation displayed led to the suggestion to reduce the number of centre blast holes as the average rock size is still quite small and powdery/dirt. Potential credibility was seen by the positive outcome of the overall

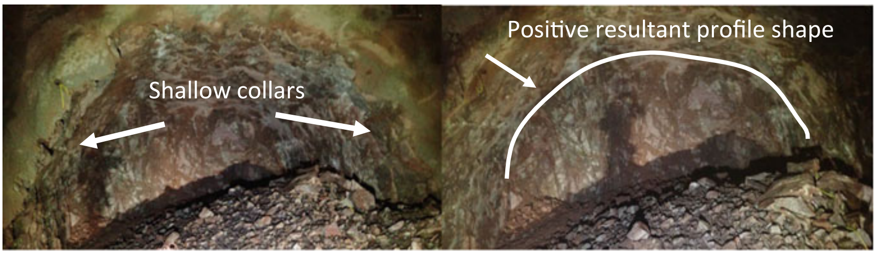


Fig. 7 ESD 001 second trial

profile seen on the bottom profile surface at the rear of the cut. This indicated that the adjustment in perimeter holes was a success and can stay the same during the next blast.

The main goal of the third trial in the 4580 ESD 001 was to reduce the number of blast holes in the centre of the drill design. The perimeter hole adjustment was successful in the second trial and it was decided to leave that as it was. As seen in the drill design, a complete row above the burn was removed and the spacing between the easer holes above the burn was increased (Fig. 8).

The inspection after the blast using the third version of this drill pattern proved to have a positive outcome. There were no oversized rocks, indicating good fragmentation. Figure 9 demonstrates that there were not any butts on the bottom profile face and no sign of collars remaining on the face profile surface. An even throw of material was produced during this blast and there was enough explosive to 'heave' and displace the material.

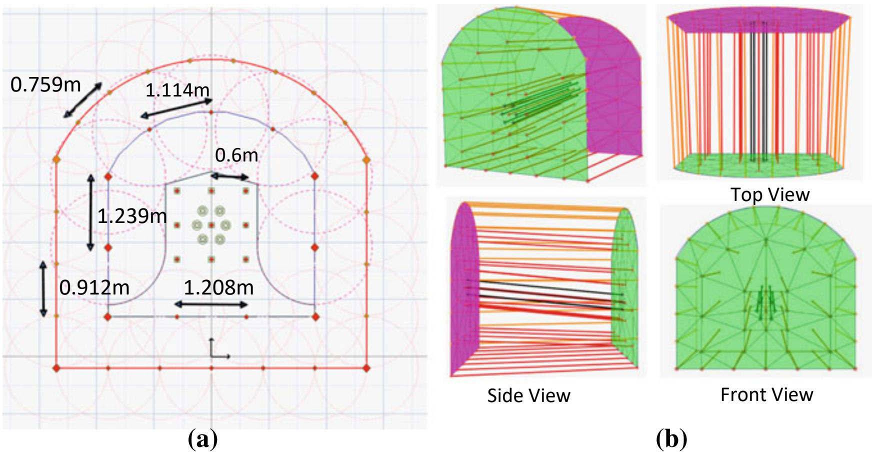


Fig. 8 **(a)** ESD 001 third trial (4580 ESD 001 47.7 m). **(b)** Three-dimensional modelling (top, side and front views), 47.7 m

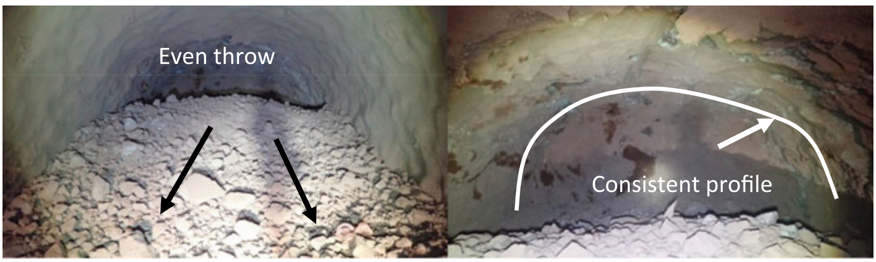
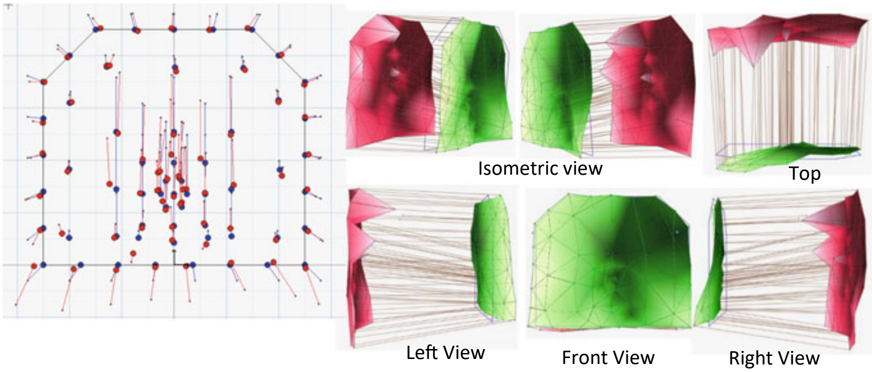


Fig. 9 ESD 001 third trial



(a) (b)

Fig. 10 **(a)** 4580 SMP 001 Second trial—planned versus drilled. **(b)** Three-dimensional view, Drill plan E_5.0 × 4.5_1in6down_V2

The inspection after the blast using the third version of this drill pattern proved to have a positive outcome (Fig. 9). Oversized rocks were not indicating good fragmentation. From what was visible there were not any butts on the bottom profile face and no sign of collars remaining in the face profile surface. It was good to see an even throw of material during this blast and to see there was enough explosive to 'heave' and displace the material.

2.3 *Drill Plan E_5.0 × 4.5_1in6down_V2*

Operator feedback suggested the burn to be higher as it was hard to drill the burn with the long booms and the angle of the burn-in conjunction with the angle of the cut. It was suggested that the burn be moved 0.5 m higher to accommodate the boom movements and make it a lot easier (Fig. 10).

It is seen that there is a large protrusion in the bottom profile surface, this is not what was eventuated in the blast results as seen in the inspection photos but is to do with the automatic data extrapolation in the jumbos computer system regarding the stub holes.

An inspection of the blast result was carried out after re-entries were complete (Fig. 11). For this heading the opportunity arose to carry out inspections after the blast and after it was bogged out.

The new drill plan for 4555 ACC-001 is T_5.8 × 6.2_1in6down_v2 (Fig. 12). The drill pattern profile names have been changed from displaying the dimensions first to having the allocated profile letter followed by the dimensions.

The first trial reducing drill holes in the T profile resulted in an increase in spacing in the perimeter holes including the backs, walls and lifters (Fig. 13). The burn

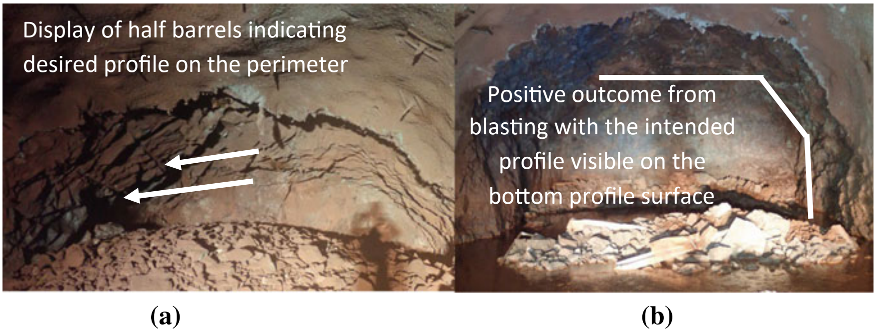


Fig. 11 **(a)** 4580 SMP 001 first trail, after blasting. **(b)** 4580 SMP 001 first trial, after bogging

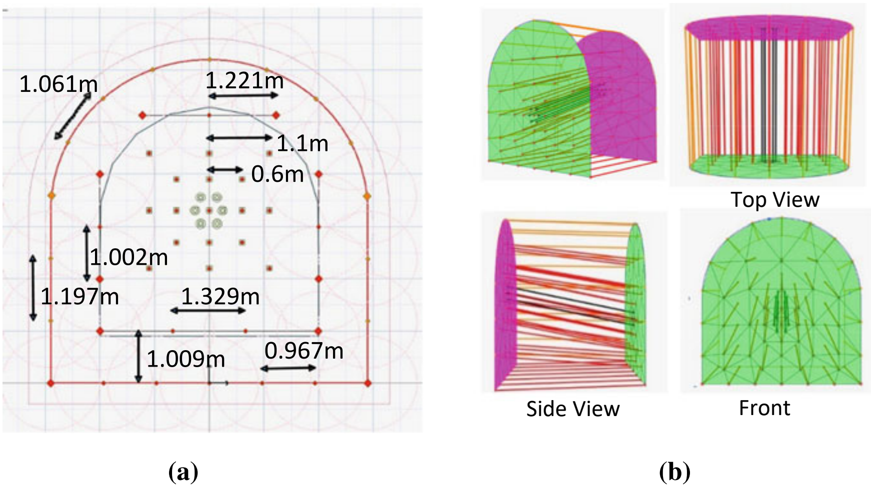


Fig. 12 **(a)** 4555 ACC 001 first trial, Chainage: 42.6 m. **(b)** Three-dimensional modelling, 4555 ACC 001 first trial, Chainage: 42.6 m

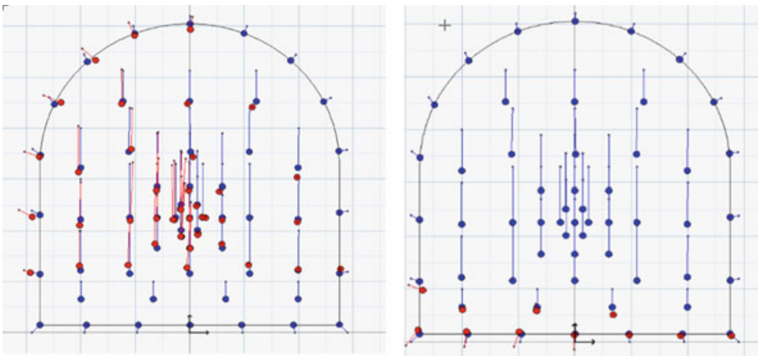


Fig. 13 4555 ACC 001 first trial—planned versus drilled

Fig. 14 4555 ACC 001 first trial

was expanded by 100 mm in both the inner and outer box. A row of knee easer holes was removed and subsequently the general spacing in the field lines increased. The heading was bogged before an inspection was possible. From bogger operator feedback the fragmentation was a good consistent size (Fig. 14).

3 Discussion

The initial intention of the drill and blast optimisation was to compare the effect of pattern alteration with the outcome of overbreak. The majority of trials had limited space in which they were conducted. This limit in space reduced the potential comparison between drill patterns as a minimum of 3 consecutive cuts are required to validate the results. Although certain headings were able to achieve 3 consecutive cuts, this was the maximum reached and therefore restricting any further comparison.

A main contributing factor that affects the data recorded was the change in geological conditions, this was present because of the difference in distance between the trials. Within the mine, there are numerous changes in geological conditions as both the depth and lateral position change and the rock behaves differently when it is under different in situ stresses and contains different characteristics. Different characteristics and rock parameters influence the results of a blast pattern. From this, it is not possible to compare the already revised patterns in each heading against one another.

Beneficial information that can be analysed is the costings that have been calculated from information collected regarding UJ003. The common perception that a reduction in only a few holes is not beneficial has been seen to be held across numerous operators, in the enlightenment of the above figures based on averages calculated from the last five-eight months small revisions can be seen to affect the financial outcome greatly.

Singular drill holes have multiple aspects that create cost reduction if mitigated in the design stage. Alongside the obvious reduction in drill metres, each hole contains a specific amount of emulsion, a detonator and a booster. Costing has been calculated to correlate the consumable cost per metre drill and percussion hour cost per metre on average over the last five-eight months.

The outcomes and learnings discovered from using various plans have a major benefit on the rest of the project when the opportunity arises to have consecutive cuts within similar drives and geological conditions. Each heading that was investigated produced different results which contain specific aspects that in conjunction with each other will create a better understanding further down the track in future trials.

4 Conclusions

The cross-sectional slices computed from Deswik demonstrated the overall over break value for the trials in the 4580 XCD 326 has an average of 7.91%. For the 48 mm comparison, this average value surpasses the expectations of what was thought was going to be achieved.

It is noted that the calculated overbreak value over the entirety of the cross-sectional slices is within an acceptable limit it was found that the laser within the 4580 XCD 326 was out of alignment by 0.4 at 80 m down the drive. Having these trials conducted from 36 to 60 m this misalignment would have severely impacted their results giving higher over break values than what was eventuated. Although this error is not documented within the deswik program as it was found to be an issue after the survey picks up was completed it is a factor that needs to be considered when comparing the results between the 48 mm design and the above 51 mm design as it would skew the notion that the 51 mm design was not as effective as it was. Given the error was found over an 80-m length there is no quantitative data that can be subtracted from the overbake value to give a conclusive result to define the figures found between 36 and 60 m.

From a couple of months of trials, it can be seen that with the implementation of progressive adjustments, optimisation can be achieved over numerous headings throughout the underground mining process. Although the results that have been presented display a benefit and improvement of what was originally being implemented in the ore drives at the mine, but there is still room to further improve these designs. A project of such will always continue to be adjusted due to the ability of the geological conditions to change quite quickly given the rapid development rate. Moving forward it will be seen that UJ003 will continue to bore cuts using the 51 mm drill bits as the above research suggests that there has been a significant cost saving while resulting in an acceptable overbreak value.

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