Long hole plug – addressing the hazard of bogged rods in 'upholes'

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ABSTRACT

Stuck drill rods (often referred to as bogged rods) in production 'upholes' are a common problem in the underground mining industry. Bogged and broken off drill rods have the potential to fall out of the hole without warning, posing a serious hazard to personnel and equipment below.

Current industry practice to alleviate this hazard can be to either grout the hole in order to lock the drill rods in place, or to 'plate over' the hole with a rock bolt. Each of these operations seriously delays mine production as both require demobilisation of the production drill and mobilisation of alternative personnel and equipment to address the hazard. Both methods have been assessed for safety and efficiency and were found to be expensive, time consuming and in the case of plating over, ineffective.

To address the safety and efficiency short-comings of the traditional practices, the long hole plug (LHP) has been developed to safely secure the lost rods in the hole. The LHP when struck by falling drill rods behaves similar to an expansion shell anchor transferring the axial forces from the falling drill rods horizontally into the rock mass. It is installed using standard production drills allowing work to safely continue with little interruption.

Extensive testing has been carried out on the LHP in the laboratory and underground at the Rosebery mine on the west coast of Tasmania, Australia. Testing has included static pull testing, full scale drop testing and underground trials.

The outcome of this work has proven the LHPs ability to add safety, volume and cost benefits to the Rosebery underground operation and it is currently in use at that site. It enables proven elimination of a common workplace hazard immediately, thus eliminating delay on the mine's production cycle.

INTRODUCTION

Bogged drill rods in 'upholes' are common problems in the underground mining industry. Bogged rods have the potential to fall out of the hole and pose a serious hazard to personnel and equipment below. Current industry practice to address this hazard is to grout or 'plate over' the hole with a rock bolt. This involves demobilising the production drill rig and using a bolting rig and/or grouting equipment to secure the hole before work can continue beneath.

The current practice at Rosebery is to 'plate over' the bogged drill rods. This delays production activities in the work area and requires a jumbo to tram to the site to 'plate over' the hole.

Rosebery has recently completed trials on a tool called a long hole plug (LHP) and it is currently in use. This device removes the hazard posed by bogged drill rods in 'upholes' and is installed using standard production drills with no rig modifications required.

The LHP has been extensively laboratory tested in Melbourne, as well as field tested underground at the MMG Rosebery mine. Tests have been 100 per cent successful in controlling the hazard posed by bogged drill rods falling from an 'uphole'. Test work has also indicated that the current industry practice of 'plating over' drill rods is ineffective and this is also covered in this report.

The LHP is in line with the MMG company values 'Safety first' and 'We want to be better'. Adoption of the LHP has demonstrated both safety and cost benefits to the MMG Rosebery underground operation and has application for all underground mines that drill 'upholes'.

ROSEBERY MINE

The MMG Rosebery mine is located on the west coast of Tasmania, Australia as shown in Figure 1. The orebody dips at 45º and is located in a foliated rock mass. Stresses around mining fronts are high and poor ground conditions are often experienced during production drilling.

Rosebery currently uses three Atlas Copco M6C production drills. Longitudinal bench and slash stoping are the two main mining methods used. Slash stoping consists of 100 per cent uphole drilling and bench stoping is a mixture of both uphole and downhole drilling. Bogged drill rods are common with

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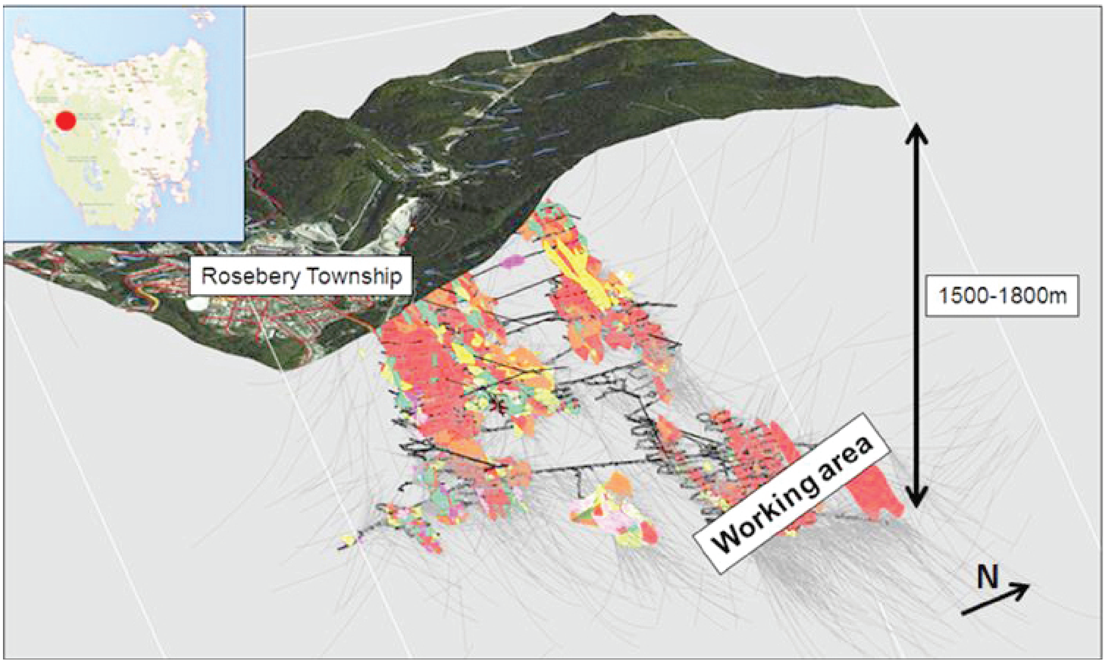

FIG 1 – Location of the MMG Rosebery mine on the west coast of Tasmania showing the location of the underground workings in relation to the Rosebery township.

both stoping methods and have safety and production implications on-site resulting in a negative impact on the business' bottom line.

CURRENT PRACTICE

There are two main methods for addressing the hazard of bogged rods in 'upholes' currently used in the underground mining industry:

1. 'plating over' with a rock bolt, nominally a split set
2. grouting the hole.

The MMG Rosebery mine employs the 'plate over' the hole method with a rock bolt, nominally a Sandvik 2.4 m MD bolt.

Plating over a drill hole has many limitations; these include, but are not limited to:

- inconsistent installation between operators
- proximity to other production holes
- operational ineffectivenes.

'Plate over' drop test

To determine the effectiveness of the 'plate over' method a drop test was conducted. The drop test consisted of:

- 89 mm ID steel casings which were used to replicate an 11 m vertical hole
- a 5 m length of 76 mm DIA drill rods.

The drill rods were allowed to free-fall 7m down the casing, as shown in Figure 2 to simulate the bogged rods falling out of a hole. This was considered a relatively conservative test because typical 'upholes' drilled at Rosebery are 20 m in length.

The simulation determined that the MD bolt and plate offered minimal resistance in decelerating the forces and failed to stop the falling drill rods. This test proved that in the event bogged rods are released from an 'uphole' there is a significant risk that the current method of 'plating over' will offer little to no protection to personnel or equipment beneath as shown in Figure 3.

As a result of this test MMG engaged the Geotech Group to design a system that would overcome the problem.

FIG 2 – 'Plate over' drop test set-up at the Geotech Group yard in Port Melbourne, Victoria.

Geotech are a Melbourne based company that have extensive laboratory and testing facilities together with an excellent workshop that was used to manufacture prototypes.

Initial discussions indicated that it would be desirable to have the chosen method be a robust unit that utilised the production drill for operational effectiveness. It also needed to be installed safely, quickly and most importantly be effective in removing the hazard posed by bogged drill rods.

FIG 3 – Completed plate over test. The MD bolt and plate offered little resistance in stopping the falling drill rods.

Initial designs utilised an oversize slotted tube that could be driven into the hole by the production drill with the falling drill rods being stopped by the frictional forces developed by the slotted tube and the side of the hole. Several tests were conducted by drilling holes in specifically cast concrete blocks, driving the slotted tubes into the holes and pulling the tubes from the block with a calibrated hydraulic jacking system. Several tests were conducted which showed the frictional forces were not adequate for the design forces developed by the falling drill rods.

A tapered wedge system was also trialled which worked effectively but was considered not robust enough for practical use. Further development and testing was carried out on various modifications until the final accepted method of a tapered cone fitted internally in the slotted tube fulfilled all the requirements.

LONG HOLE PLUG

To address the safety and efficiency short-comings of the traditional practices, the LHP was developed to safely secure the bogged rods in the hole. The LHP has been designed to be installed by a single operator using standard production drills and does not require any rig modifications. It consists of two components as shown in Figure 4 that engage to decelerate the forces generated from falling drill rods:

Cone section	machined out of solid bar
Slotted tube	100 mm OD, 8 mm wall thickness, pull out resistance 120 kN (for 89 mm LHP)

The LHP is installed using percussion and is held in place by the slotted tube component. When the rods fall they strike the cone section driving it into the slotted tube component as shown in Figure 5. The LHP then behaves like an expansion shell anchor by transferring the axial forces from the falling drill rods horizontally into the rock mass.

The LHP is a robust unit. The cone section is machined from solid bar onto which the slotted tube component is pressed. This makes the LHP easy to find in the ore stream by magnets and metal detectors. Being a robust unit there is minimal chance for components to break thus reducing the chance of metal making its way into sensitive milling equipment such as crushers.

The female drive coupling has been designed slightly over size so as the drill rod shoulder drives the LHP into the hole. This avoids potential damage to threads on drill rods and shanks.

The cone section has a 200 mm 'lead in' which allows for the jaws of the production drill to hold the LHP in line with the drifter. A sacrificial wooden dowel serves as a locator to ensure that the jaws engage the 'lead in' thus keeping the alignment. It also serves as a hole locator for installation, this is particularly important due to the rigid nature of the booms on some production drills.

The LHP needs to be installed a minimum of 1000 mm in competent rock to arrest a falling drill string.

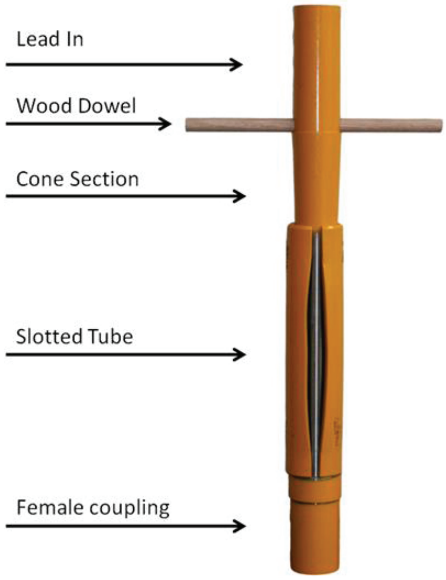

FIG 4 – Long hole plug components.

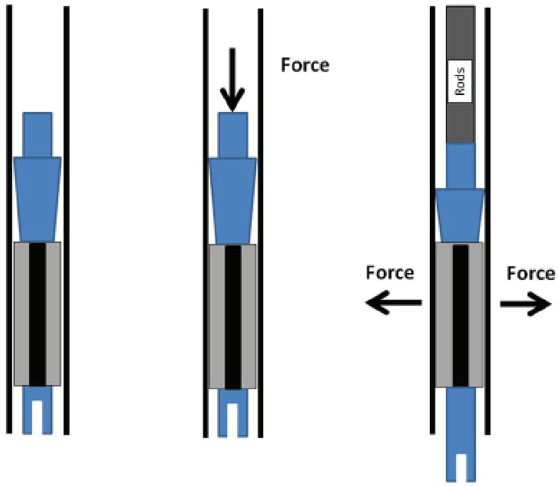

FIG 5 – The long hole plug is held in place by the slotted tube component. It is only when the rods fall that the cone section engages the slotted tube, this action transfers the forces of the falling drill string horizontally into the rock mass.

LABORATORY TESTING

LHP test work to date consists of the following two categories which will be discussed individually:

1. static pull testing of the slotted tube component
2. full scale drop testing.

Static pull testing

The slotted tube component of the LHP holds the device in the rock mass until such a time that the cone component is engaged. The slotted tube component achieves static pull out resistance of 120 kN prior to mobilisation in 80 MPa concrete.

Full scale drop testing

A total of 42 full scale drop tests were conducted on the LHP.

A 50 m vertical hole was replicated using 89 mm ID steel casings bolted adjacent to a cement conveyer tower. A drop mass of 574 kg (25 m length of 76 mm DIA drill rods) was able to free fall 25 m onto the LHP installed in precast concrete blocks (Figure 6). This combination represented the maximum force of 140 tonnes at the hole collar for a 50 m hole containing bogged rods.

The LHPs were installed in heavily reinforced concrete blocks by drilling an 89 mm hole in the concrete block, then driving the LHP into the hole using percussion only.

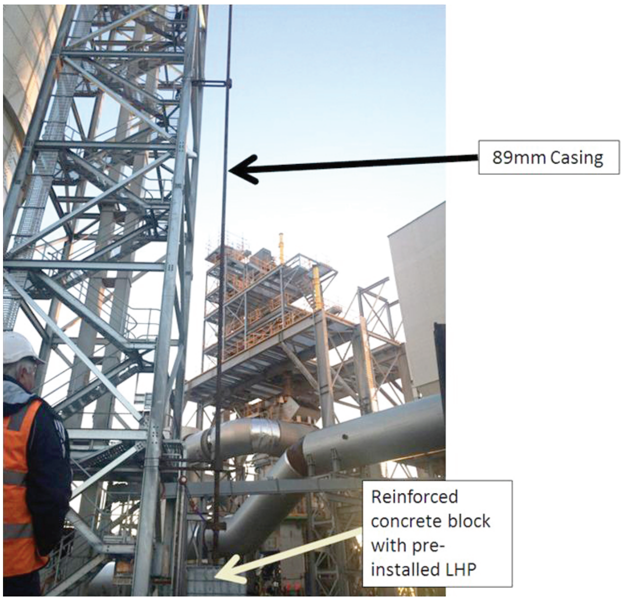

FIG 6 – Long hole plug full scale drop test set-up in Melbourne. 89 mm ID drill casings were bolted to the side of a cement conveyer tower. A 574 kg length of rods was then lifted and released down the casing onto the LHPs, which were installed into precast concrete blocks. A total of 42 full scale tests were conducted with the LHP arresting the drop mass between 100 to 150 mm in every test.

The LHP was successful in arresting the drop mass in every test between 100 to 150 mm.

FIELD TESTING

Prior to the LHPs implementation on-site at the MMG Rosebery mine, three field tests were conducted to assess the following criteria:

- safety of installation
- effectiveness in the Rosebery rock mass.

Tests were conducted in the 53W_HWD1850 and 52W_DDC1770 (Figure 7).

Safety of installation

A safe installation procedure was required prior to testing the LHP. This covered issues such as manual handling, working around the boom of the drill and isolation of the rig. Once this was completed a risk assessment was conducted with no safety issues identified.

The LHP was installed in the shoulder of the 53W_HWD1850 with no safety or operational issues identified and positive operator feedback received.

Effectiveness in Rosebery rock mass

Two *in situ* drop tests were conducted on the LHP to assess its effectiveness in the Rosebery rock mass. The tests were conducted in 39 m long holes drilled between the 50W and 52W levels. Both tests were successful in arresting the falling drill rods over a maximum distance of 150 mm (Table 1).

All three LHPs were installed in close proximity to blasting activity and have remained in place up the hole.

TABLE 1
52W_DDC1770 LHP drop test results.

Hole ID	Hole length (m)	Dump	No rods dropped	Stopping distance
1	39	9°	10 rods	150 mm
2	39	9°	5 rods	110 mm

FIG 7 – Long hole plug being installed in the northern shoulder, 53W_HWD1850.

UNDERGROUND APPLICATION

The LHP was introduced to the underground workforce at Rosebery as a safety and productivity improvement to the current practice of 'plating over' bogged rods. All long hole drill operators and shift supervisors were taken through the installation work instruction and trained in how the LHP works.

The LHPs are used regularly when drilling upholes in poor ground conditions. Feedback from operators and management has been positive due to the ease and speed of installation allowing more time to focus on safely achieving shift targets without having to disrupt personnel and machinery.

ADVANTAGES FOR USE AT ROSEBERY

The driving factors within the MMG Group are safety, volume and cost. The adoption the LHP at the MMG Rosebery mine has advantages for all three driving factors.

Safety

- The current practice for addressing the hazard of bogged drill rods was demonstrated to be unsafe and ineffective. If the rods were to dislodge from the hole 'plating over' will offer inadequate protection to personnel and equipment below.
- Use of the LHP removes the hazard of bogged drill rods immediately. This eliminates the chance of the hazard being forgotten between shifts or the wrong hole being 'plated over' at a later date.
- As the LHP is installed with a production drill there is a reduction in heavy machinery movements around the mine as the jumbo is no longer required to 'plate over' the bogged rods.

Volume

- Increased production drill availability:
  - It takes approximately 5 minutes to install the LHP and it removes the requirement to demobilise the production drill. This has significant time savings as the hazard is promptly rectified by the same machine operating in the level, allowing production drilling to continue virtually unaffected.
- Equipment efficiency:
  - Elimination of the requirement to tram a jumbo from elsewhere in the mine to address the hazard. Given Rosebery's mine layout the time taken to tram a jumbo to and from a production drill site can be several hours.
  - Increased jumbo and long hole drill utilisation for productive activities.
- Reduction in stope delays:
  - Removal of the requirement to 'plate over' lost rods further streamlines the production process from drilling to firing.

Cost

The major cost saving of the LHP is in the reduction in downtime for production and jumbo drills.

- Production drills:
  - The major cost saving associated with the LHP is in the significant reduction in production drill downtime when addressing the hazard of bogged rods in 'upholes'. This downtime can be equated to lost production drill metres. When comparing the LHP to the 'plate over' method a total downtime of three hours for the 'plating over' method has been used. This figure is considered conservative due to the rig tram times, mobilisation and demobilisation times and general mine delays.
  - For every minute that a production drill or development drill is not carrying out productive work it is negatively impacting a company's bottom line. In many operations the bottleneck for productivity rests on drilling out and blasting stopes so that ore can be continually delivered to the surface. Any delay in this activity needs to be reviewed to determine if there are other options that have a superior opportunity cost than current practice. In this case, the LHP has unparalleled advantages as it gets the same job done faster with the same production rig to a measured safety standard.
- Jumbo drills:
  - At Rosebery it takes approximately four hours for a jumbo to *bolt – mesh – bore* a standard cut. As above, a jumbo downtime of three hours has been used to compare the LHP with the plate over method. Three hours of 'lost' jumbo time equates to half a cut *bolt – mesh – bored* or in dollar terms approximately $6500. Depending on the amount of holes that require plating over this can become a very expensive exercise.

SUMMARY

Uphole drilling is very common in underground mines. Bogging drill rods occurs due to a range of reasons such as driller experience, ground conditions, drill performance and the condition of the drill consumables. There are many factors such as ground movement which can cause a bogged drill string to dislodge from an 'uphole' posing a hazard to personnel and equipment working below. The lack of effectiveness and productivity of the current hazard control methods has led to the development of the LHP which safely removes the hazard posed by bogged rods, improves productivity and is cost-effective.

In the current market of increased safety demand and tighter cost control mines must look to streamline their operations to safely minimise downtime and maximise production. The development and implementation of the LHP at the MMG Rosebery mine has added value to the operation by increasing operator safety and reducing production drill downtime.

ACKNOWLEDGEMENTS

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