In-stope bolting for a safer working environment

by P. Henning* and P. Ferreira*

Synopsis

Rock fall accidents continue to be the main cause of fatal and serious injuries in the mining industry. Although there has been an improvement in the FOG (falls of ground) related fatal and serious injuries over the past few years, the rate is still too high. New technology has made it possible to reduce this rate significantly. FOG accidents imply failure of the support system or the design of the support system in use. In this paper we deal with the latest technology available to assist the mines to reduce the rates of FOG related injuries and fatalities.

Introduction

Reliable and permanent rock support is the main focus in the mining industry to minimize the risk of FOG related injuries and fatalities. To achieve the objectives of the safety milestones agreed by the industry, there is an ever increasing demand to improve technology and systems to combat injury and death of workers in the mines. Failure or inadequate support of conventional narrow vein stopes still result in injuries and fatalities. Stopes are supported to ensure safety of the workforce, but injuries and fatalities still occur from time to time. This is a clear indication that something different needs to be implemented in addition to the measures already in place to improve the safety situation on the mines. During 2008, 57 lives were lost due to FOG related injuries on SA mines. (DME Annual Report 2007). This is 57 too many. 748 people were seriously injured by FOG. The mines lose revenue due to the resultant workplace stoppages.

Mining and engineering experts understand the need to improve safety on the mines. Because of their constant research and development of support systems, new technology becomes available to help mines meet their safety objectives.. Mines that appreciated the potential and introduced in-stope bolting, achieved a remarkable decline in rockfall accidents/incidents in their working places.

However, the tendency since inception of this practice had been to use the same rock drilling machine used to drill the working face (usually compressed air operated) to drill the roof support holes. As a result, holes are normally obliquely drilled due to height constraints, thus not yielding the desired hole length and angle.

A further development was the invention of the remotely controlled 'Autorock' mini stope support drill, rig which has given the industry a sense of hope and optimism towards realizing the 2013 targets and milestones. The remotely controlled 'Auto Rock' mini stope drill rig was introduced to the mining industry in 2002 and to date more than 3,000 units are being used all over the mining industry of South Africa.

The 'Autorock' mini support rig also achieved a prestigious 'Design Excellence Award' from the SABS in October 2008. The advantage of having a remotely controlled in-stope mini support rig, which is able to drill support holes between 70° and 90° in low stoping widths, varying from 800 mm up to 4.5 metres, was soon realized by the mines. The rig also features rigid clamping rods securing the rig between the hanging and footwalls of the stope excavation for added safety until the bolt installation is complete. Where use is made of resin support tendons, the 'Autorock' rig is also used to spin the resin bolts home, creating a very effective support system minutes after the installation, owing to the high bond strength between the rock and steel provided by the full column resin.

* *Minova RSA.*

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Conventional narrow reef support systems

On most of the mines where the conventional stoping method is applied, the stopes are temporarily supported with mechanical props or jacks. These are usually removed before the blast, leaving the space between the work face and the permanent support unprotected. Many persons have been seriously injured during the removal of temporary support and some have been fatally injured. During the blast, this excavation is further increased, creating unsafe hangingwall conditions for the cleaning shift entering the working face. Timber, cementitious packs or prestressed elongates are then used for permanent support:

Tempory support followed by permanent support has the following drawbacks:

- ➤ Low productivity
- ➤ Support medium must leave path for the mechanical scraper
- ➤ Bulky and adds to logistical problems
- ➤ Persons exposed to unsafe hangingwall conditions
- ➤ Support cannot be installed right up to the work face
- ➤ Support has low stiffness
- ➤ Support at risk of being blasted out
- ➤ FOG still occurs.

In-stope bolting as a narrow reef support system

- ➤ The installation of roof bolts as a temporary and also primary support in stopes and gullies in conjunction with packs, prestressed elongates and props guarantees added safety on the work face
- ➤ Resin anchors, end-anchored bolts, cemented or friction bolts can be used
- ➤ Support holes can be drilled from a remote, safe position using an 'Autorock' mini support drill rig
- ➤ Support tendons can be installed right up to the face prior to the blast resulting in:
  - – FOG accidents/incidents drastically reduced.
  - – Good support area coverage leads to improved hangingwall conditions
  - – Support density can easily be increased to consolidate geological features
  - – Improved safety at the work face
  - – Improved stoping width control—ease of undercutting and supporting of brows
- ➤ Single support cycle replaces two cycles, i.e. temporary support stays in as a primary or permanent support.
- ➤ Face area left clear for people and equipment to manoeuvre.
- ➤ No obstruction of scrapers or mechanical cleaning plants.
- ➤ Reduced timber requirement depending on the ground conditions.
- ➤ Reduced timber requirements will have the following advantages:
  - – Less material to transport
  - – Lower costs
  - – Labour saving
  - – Higher speed of construction

With bolting installed, there is a reduced risk of potential personal injury due to FOG because of enhanced safety, which protects workers between the stope face and the permanently supported area, defined as the 'critical risk area'(CRA) both during drilling and cleaning operations. Since introducing instope bolting, mines have shown significant improvements in their FOG casualty rates.

Mines not making use of in-stope bolting should seriously consider implementing the system to assist with the reduction of FOG incidents in order to safeguard their people. Quite often you will hear the remark, 'In-stope bolting is too expensive. We have mined without it for years, why should we consider it now?' The same mine can then afford millions of rands when working places are stopped because of unsafe working practices.

Why the need for in-stope bolting?

- ➤ The immediate skin of rock around the excavation is weakened by the blasting, exposure, and stress
- ➤ The depth of fracturing (penetration) into the solid depends on a number of factors, and in general can be up to 5 m for some stoping operations
- ➤ Horizontal clamping forces are induced in the rock mass that tends to knit the rock together in a more coherent beam
- ➤ Key blocks are always present and dislodging of one or more of these could lead to an uncontrolled fall of ground
- ➤ Fracturing might in some cases terminate on dominant geological structures such as bedding planes or joints. since the latter are associated with a different mode of rock mass behaviour and characteristics
- ➤ It is important to know that the face is not recognized as support. The reason for this is that the face and hangingwalls are fractured due to the position of the stress fractures created by the advancing face and hangingwall convergence.

These aspects are best illustrated in Figure 1. Take note that it is a simplified model of the actual fracture profile around underground excavations.

Support mechanism of roof bolting in stopes

Due to the face to permanent support distance, inelastic closure is allowed to occur, (separation of bedding planes).

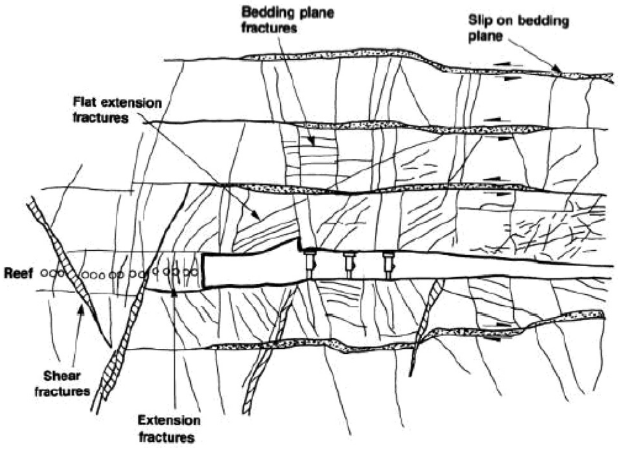

Figure 1—Section view of a typical underground stope environment

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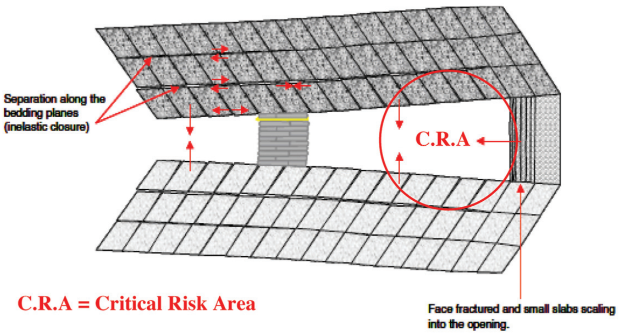

Figure 2—Sectional view showing typical stope closure

Falls of ground occur within the face area as result of poor

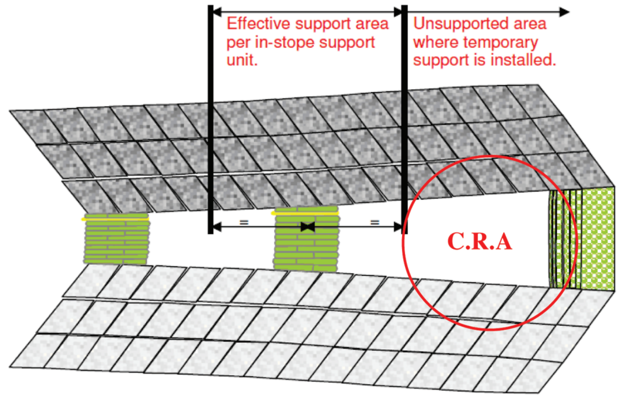

Figure 3—Diagrammatic section depicting the effect of a normal stope design

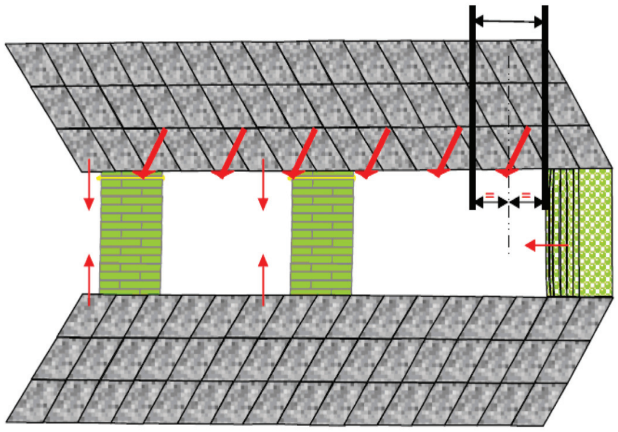

Figure 4—Section view of a typical in-stope roof bolting installation

blasting practice in conjunction with bedding plane separation and geological features. In most cases the proper installation of a good bolting system will control falls of ground in the CRA. By installing a rock bolt, it assists in reinforcing the hangingwall beam being created by the effective length of the rock bolt. If one reinforces the beam, it deflects and reacts almost elastically, controlling the inelastic closure. Separation along the stress induced fractures is minimized as the bolting results in the clamping of these fractures.

In-stope bolting knits the stress/blasting induced fractures, jointing and other geological discontinuities mentioned above, thus limiting wedge type fallouts/ separation along stress/blast induced fractures. (Figure 5–6.)

Classification of accidents

Although there has been a 22.2% decrease in the fall of ground fatality rate from 0.09 in 2006 to 0.07 im 2007, Figure 7 shows that fall of ground accidents are still the largest contributor to the cause of fatalities in our mines. A total number of 76 lives were lost as a result of fall of ground accidents in 2007.

There has been a decrease in rock related fatal accidents subsequent to the implementation of preconditions and in-stope roof bolting. However, there is an alarming increase in fatal accidents, other than the rock related fatalities, in the gold sector.

FOG remains the biggest threat to the safety of the people working underground. Although there have been considerable improvements over the past few years, there is a lot that can still be done to improve the safety situation on the mines. DME gives a lot of credit for the improvement in FOG statistics to the implementation of in-stope bolting on the mines.

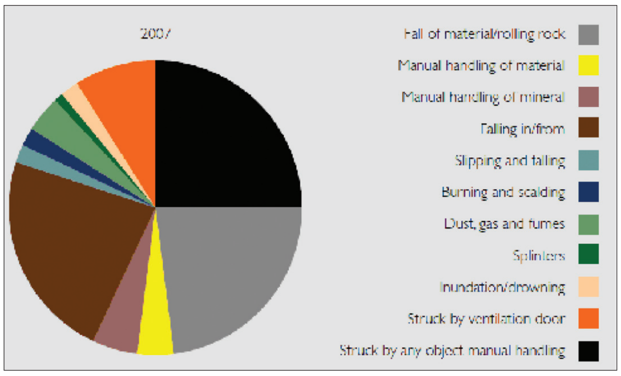

Figure 5—General accidents class contribution

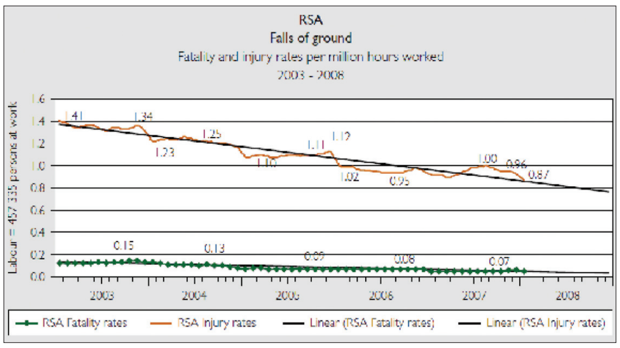

Figure 6—Falls of ground accident rates

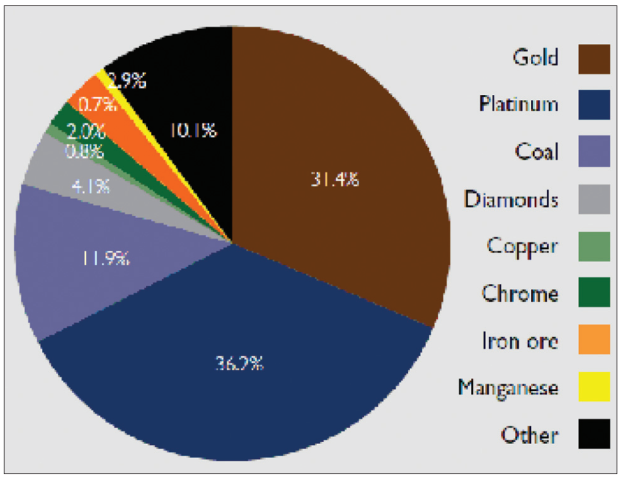

Figure 7—Labour percentages per commodity

Some statistics of mines that implemented in-stope bolting

Elandsrand mine implemented in-stope bolting in March 2006. Total FOG accidents pre- and post-implementation of in-stope bolting are shown in Figure 8.

In-stope bolting began at Modikwa Platinum Mine in August 2003. Since then there has been a marked reduction in the number of injuries as a result of FOG accidents/incidents. (Figure 9.)

Both safety and productivity have been improved. Rockbolts are installed within 0.5 m of the face, improving hangingwall suppport in front of the first line of elongates. Significant safety improvements are anticipated because mine personnel are at reduced risk from falls of ground. Ore dilution is also significantly reduced, resulting in a 'win-win' situation.

In-stope bolting making use of an auto rock remotely operated mini stope support drill rig

General features of an autorock drill rig

- Portable – 750 model weighs only 45 kilograms
- Require only one person to operate in low stoping widths
- Operate from the compressed air and water lines available in the stopes
- Can operate from air pressures as low as 3 bar; (air pressures from 4–6 bar recommended for optimum performance
- Operator exposed to reduced noise, owing to remote operation
- Operator not exposed to the severe hand vibrations experienced with hand held jack hammers
- Built in clamping rods secure the Autorock between hanging and footwall of stope during drilling. This enhances drilling accuracy. Although the clamping rods offer some support, tempory support is still required to comply with the mine standards whilst operating the rig
- When making use of resin bolts for support, the Autorock rig can also be used to spin the resin bolts home, which provides an active support system within minutes of the installation. Bolt installation is completed before the rig is moved to the next support hole position. (Figure 11.)

Advantages of using an autorock rig for in-stope bolting (Figure 14 and 15.)

- Improved safety/hanging wall conditions
- Improved productivity
- Support holes can be drilled between 70° and 90° in stoping widths varying from as low as 800 mm with the smaller drill rigs up to 4.5 metres with the larger units

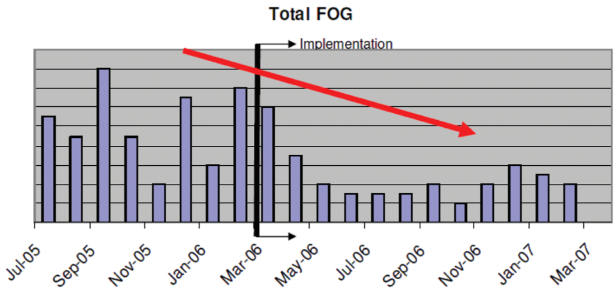

Figure 8—FOG accidents pre- and post-implementation of in-stope bolting at Elandsrand mine

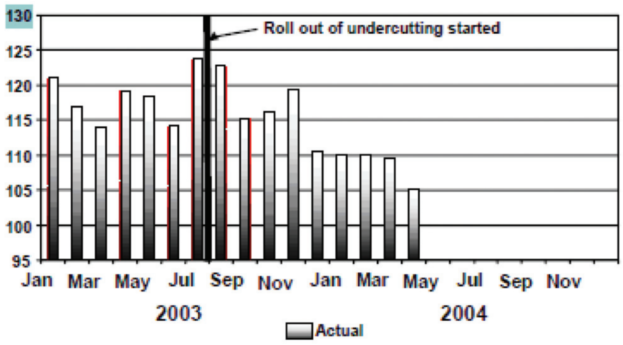

Figure 9—FOG accidents/incidents at Modikwa Platinum Mine

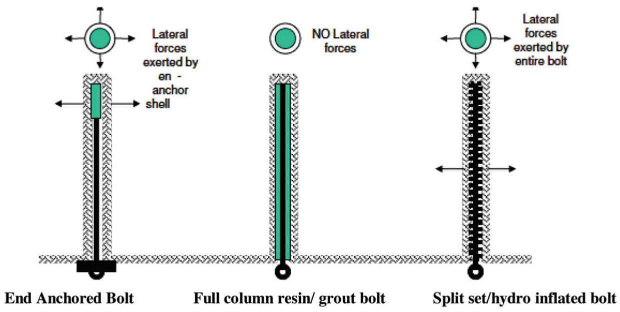

Figure 10—Bolts that can be used with in-stope bolting

Table I

Characteristics of bolts used for in-stope bolting

Characteristics	End anchor/rock stud	Resin/full column grouted	Hydro Bolt	Split set
Equipment requirements	T- spanner/pneumatic torque wrench	Spinning adaptor/grout pump	25 Mpa pump, hoses and couplers	Pusher dolly
Installation time	60 seconds	60 seconds	60 seconds with pump in good working order	60 seconds+
Full column support	No	100%	Approx 85%	Approx 85 %
Active support	Yes – if properly tensioned	Active when 2 speed resin system is used and tensioning is done before the setting time of the 5/10 resin	Yes – if properly inflated	Yes – providing hole diameter is correct
Typical peak load	10.5 tons	15.5-17 tons	10.7 tons	5 tons- slip in excess
Installed reliability	70%	90%	80%	85% depending on proper installation
Sensitivity to under size borehole dia. (e.g.) bit wear	Not generally sensitive	Sensitive when oversized holes are drilled. Recommendation is to drill 28 mm holes with 20 mm resin bolts	Decrease performance due to partial inflation	Will increase. Difficult to install
Underground resilience	Damaged plate,thread, if not properly tensioned	Excellent	Good: valve damage unlikely	Good
Shear yield ability	16–18 mm	Low 7 mm	16–18 mm	16–18 mm
End anchoring and critical bond length	Anchor on shell only	Good with 2 speed resin and if tensioning of bolt is done	Friction anchoring over length of bolt	No end anchoring friction only
Comments	Expensive. Ineffective if not tensioned properly	Low cost, very strong and early strength when resin is used.	Very expensive corrosion	Corrosion- dependent on correctly drilled holes

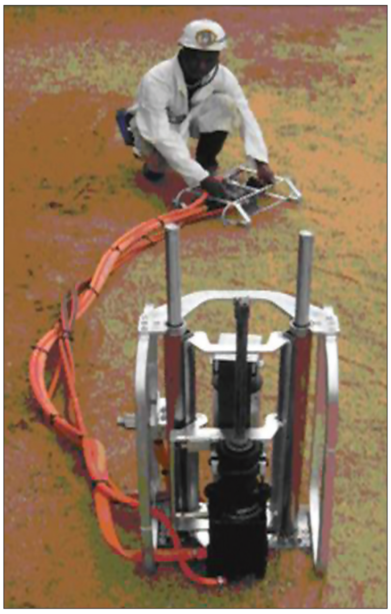

Figure 11—Auto rock drill rig

- Cost-effective support system
- Compressed air, hydro powered or electric drill can be fitted to the Autorock drill rig
- Provides a quality support system when used with an appropriate bolting system
- Any type of support tendon can be installed using an Autorock mini stope drill rig
- Support holes for the installation of cable anchors can be drilled in a low stoping width by making use of coupling drill steels
- Ease of operation. RDOs trained to operate the Autorock drill rig within 3 days
- High speed drilling. When making use of the resin bolt option, the hole is drilled and the resin bolt installed in approximately 6 minutes, provided that sufficient compressed air is available and the drill bit is in a good condition

Why use an Autorock drill rig to drill support holes and install roof bolt support? See accident statistics detailed in Figures 12 and 13.

Implementation of Autorock on the mines (is shown in Figures 14 and 15.)

Conclusion

Naturally, there has always been a resistance to change in the mining industry. 'In-stope bolting' is seen as a lot of 'extra work' and the implementation of it difficult and a costly exercise. Can the value of a person's life be calculated in rands and cents? If in-stope bolting is effectively applied in every mined panel in South Africa, lives will be saved. To implement this on any mine will cost some money, time and effort. It will also demand commitment and discipline. A culture must be created amongst all employees to work safely and create a safe working environment....

'In-stope bolting' will be the best investment any mine can make to safeguard the lives of their people.

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RDO Accident Analysis

Accident Types	No. accidents	Percentage
Misfires - drilling into	2	1%
Equipment failure	3	2%
Barring	4	3%
Transporting of equipment	5	4%
Charging-up	6	4%
On platform	7	5%
Foreign bodies in eyes	7	5%
FOG - whilst drilling	9	7%
Lost footing/balance	9	7%
Airleg slipped	9	7%
Hose connections	10	7%

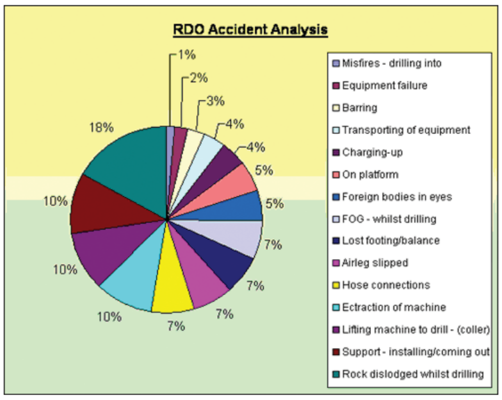

Figure 12—RDO accident analysis

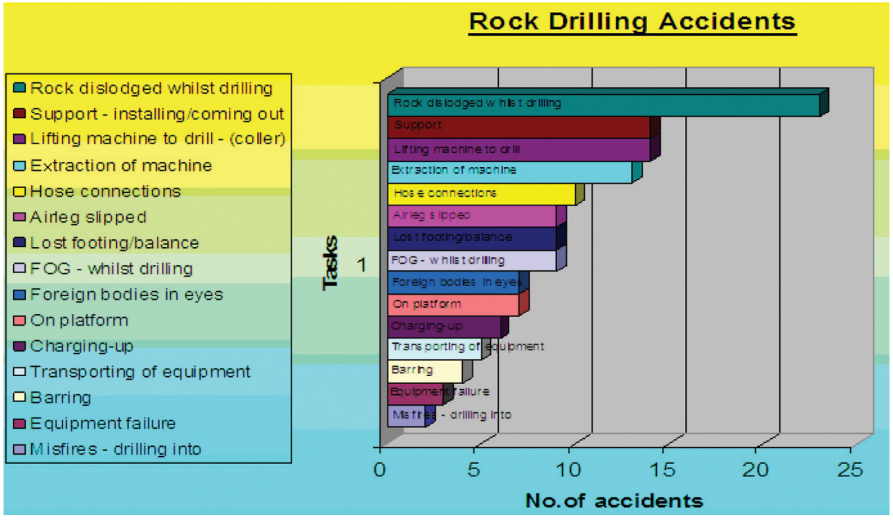

Figure 13—Rock drilling accidents

Figure 14—Autorock drilling 90 ° support holes in a platinum mine stope in the Rustenburg area

Figure 15—Drilling of support holes @ 70° towards the stope face, at a deep-level gold mine in the West Rand, in very bad ground conditions