Case study of the rockpass system at Kloof No. 3 Shaft

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Synopsis
In this paper, problems that have been experienced with the rockpass system at Kloof Mine No. 3 Shaft are described. Actions that have been taken to overcome the problems are also described. These include the use of slugshots to remove hang-ups, the abandonment and waste filling of passes, and design criteria adopted for an alternative pass system.

Brief history of Kloof No. 3 Shaft
The Kloof No. 3 shaft is situated on the northern boundary of the Kloof Gold Mine. It is commonly referred to on Kloof as the ‘King of the Hill’. The shaft was commissioned in 1980 and, since then, has experienced endless problems with the operation of its rockpass systems. It is currently commissioning a new ore pass system.

Kloof No. 3 shaft is predominantly a Ventersdorp Contact Reef shaft and is known to be one of the highest grade shafts in South Africa, with mining values above 16 grams per ton.

The shaft currently employs 2 500 people and produces between 700 and 800 kilograms of gold from 11 500 square metres mined per year.

Rockpass design and layouts at No. 3 Shaft
All rockpasses in the pass system on the shaft were 2.4 m diameter raise-bored holes in the footwall of the reef. At the shaft location, the strata dip at between 35° and 40° from north-west to south-east.

From 24 level down to 31 level, the rockpasses are ‘single level’ with lengths of 80 to 85 m. These rockpasses criss-cross the strata, with every second rockpass traversing the strata almost at right angles. The waste pass system is discontinuous, with no waste system between 27 and 28 levels. This necessitates the mixing of reef and waste on the upper levels.

From 31 level down to 43 level, the rockpasses are ‘double level’ with lengths of between 160 and 170 m. The rockpasses also criss-cross the strata and in some cases were drilled obliquely to the strata.

The rockpass system is predominantly situated in quartzite, with the Libanon dyke being traversed by the rockpasses between 39 and 33 levels. Below 41 level the rockpasses are in the Jeppestown shale formation.

History of problematic rockpasses
In 1985, the reef pass between 31 and 33 level hung up for almost two months. This reef pass was drilled obliquely to the strata. Developing an access leg to the blockage, rigging up a diamond drill machine, and drilling the big rock causing the hang-up, eventually brought it down. These holes had to be charged up and blasted to remove the blockage.

All rockpasses drilled with the strata experienced hang-ups to varying degrees. A number of new rockpasses were subsequently drilled to bypass the problematic areas. Some of the rockpasses have been abandoned and tipped full of waste.

During 1997, the original waste pass was converted to the reef pass system since it was in ‘better condition’. The reef pass system was changed to the waste system and kept as full as possible.

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By trial and error, a minimum distance from the top of the pass was determined for all reef passes and the reef was not pulled down below this level. These distances vary from 30 m in some cases to over 100 m in others. As a result of this, the current lock up of ore at No. 3 shaft is estimated to be between 20 000 and 40 000 tons.

Failure modes of the orepasses

Depth below surface obviously plays a role and is quite evident at No. 3 shaft. The ‘shallower’ rockpasses down to a depth of 2 500 m show few signs of scaling and no problematic blockages.

Scaling along strike or ‘dog earing’ is predominantly the failure mode of the deeper section rockpasses. As shown in Figures 2 and 3, this scaling occurs at 90º to the direction of action of the major principal stress—in the case of the Witwatersrand formation, the scaling direction is along strike. The longer the rockpass, the more scaling encountered. Minimal problems are experienced with the rockpass length less than 80 m, while all the longer rockpasses are problematic. There is greater impact and wear in longer passes. The estimated average cross sectional area of some rockpasses has increased 10-fold from 3.5 m² to over 35 m².

The volume, and hence cross-sectional area, was determined by the storage capacity of the rockpass. An incident has been experienced where the self-mining of a rockpass migrated into the haulage on the level below. An example of this is illustrated in Figure 3 in which rockpasses self-mined into the 39 level tip area. 30 000 tons of waste was required to fill this pass, and the filling operation took 9 months to complete.

Geological features do increase the risk of failure in rockpasses and should be avoided if possible. At No. 3 shaft the rockpasses traversing the Libanon dyke show very pronounced scaling in the dyke area. Less scaling is evident below the dyke, so any large rock would hang-up at this ‘bottleneck’.

Impact wear does occur just below the tip grizzly, but is minimal.
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The majority of the problematic rockpasses and hang-ups at Kloof No. 3 shaft are as a result of large rocks scaling. Large seismic events in the shaft pillar area are known to accelerate the scaling. The dislodged slabs drop down to a ‘narrower’ portion of the rockpass. These all occur at 20 to 40 m from the bottom. These rocks do not immediately block the rockpass. The broken rock somehow finds its way past these rocks. Some massive ‘buses’ are still identifiable after 10 years. However, as more scaling occurs, the rocks start to interlock and block the flow of rock. Examples of blockages by large rocks are shown in Figures 4 and 5.

Dealing with disrupted ore flow

All blockages normally occurred at the same place in each rockpass. Concussion blasting was used to dislodge the blockages. Access ways were developed in some cases to the normal hang-up position to deal with the hang-up. Any such access ways must be designed to go flat on the last leg. In one case an access way from 39 level into the rockpass was laid out in such a manner that the last leg would be level grade for 12 m from the centre line of the original raise bored hole. The access way holed into the rockpass even before turning level for the last leg. Entry could be gained into the rockpass using this access way, and it was possible to move around on a large rock approximately 22 m long that was lying across the original 2.4 m diameter rockpass. All access ways have subsequently been abandoned due to the self-mining into them of the rockpass.

Diamond drill holes and raisebore pilot holes were also drilled in attempts to pull up explosive charges to get them in close proximity to the blockage. Minimal successes were had using this method.

In the late 1980s, slugshots became available. A slugshot comprises 5 kg of high explosive shooting a copper slug of 0.8 kg for a maximum application distance of 60 m. Due to the high velocity of over 6 000 m/h and the inertia of the copper slug, key blocks and medium thick rocks can be dislodged or broken and assist in the removal of the hang-up. Slugshots do not work if the key rock is too thick or offers an oblique face towards the slugshot. In desperate times desperate measures are taken, and the record slugshot consumption in one month was 78, with 13 of them being blasted simultaneously at a hang-up in one case. The bulkhead was destroyed with the hang-up remaining!

In 1997, the super slugshot or Blockbuster was marketed. It uses 9.5 kg of explosives to fire a 4.0 kg copper slug over a maximum application distance of 120 m. The majority of hang-ups are now removed using this method of ‘slugshotting’ the obstruction. Normally 2 slugshots are blasted simultaneously at the key block.

Figures 6 and 7 illustrate the aiming of a slugshot and the slugshot mounted and ready to fire.
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Safe procedure when blasting slugshots

The following points summarize the actions adopted to ensure safe removal of hang-ups using slugshots.

- Concussion blast the rockpass by pushing up charges from outside in the conventional manner
- Allow at least 24 hours for rockpass to settle
- Ensure no fines are coming down by deckng off the discharge chute
- Observe that no more than a trickle of water is coming down the rockpass and the water must run clear. Do not enter if muddy water is coming down
- Push up an air hose for ventilation
- Examine for obvious loose slabs
- Install ladders to gain access for line of sight to the blockage
- Examine the area where the support bar is to be installed
- Always ensure that the escape route is unobstructed to allow for fast evacuation
- No more than two people to be inside the rockpass at a time
- Aim the slugshot at ‘square on’ corners of key blocks
- Ensure that a good spotlight is available
- When blasting more than one slugshot at a time, set off simultaneouesly by means of electric detonators.

Experiences with support and lining of rockpasses

Although some of the other shafts at Kloof have used concrete rings to support rockpasses, this has not been done at any No. 3 Shaft rockpass. Concrete lining cannot protect the rockpass at impact zones. Concrete rings do not last indefinitely and once they have deteriorated to the extent that they become detached, removal of the rings from the rockpass is a serious problem.

The application of a spray on abrasion-resistant skin, such as shotcrete with andesite lava aggregate, does assist in slowing down the abrasive wear in the rockpass, but does not prevent stress induced fracturing. Within three months of commissioning an internal rockpass system that had andesite lava shotcrete applied, big rocks with the layer of shotcrete support were being removed from the rockpass.

Rock bolting and the use of flexible tendons to support a rockpass has been done, but, within six months, the remnants of the 4.5 m tendons were coming out with scaled rocks.

Design criteria for an alternative rockpass system

An alternative reef pass system has been designed for No. 3 shaft from 35 level down to 44 level. The new orepass system has been designed to traverse the strata almost at right angles. The Libanon dyke and the shale all cut through the orepass at right angles. This has been shown to minimize the risk of stress-induced scaling.

No support of the ore pass was done due to time constraints since the current ore passes are deteriorating rapidly.

The new orepasses will be kept relatively empty in the initial stages to prevent the broken rock from forming ‘arches’. This bridging is more likely to occur in new raise bored rockpasses with smooth walls. Once the stress-induced fracturing causes the walls to scale and become uneven, bridging is less likely. Once this is evident, the orepass will be operated as full as practically possible, since it has been proven that broken rock acts as support for the rockpass and also reduces the wear due to impact.

Old reef pass system

The old reef pass system will be emptied and filled up with waste where waste is available.

At the beginning of October 2004, the process of emptying the first standby reef pass from 33 level to 35 level commenced. This 155 m long reef pass of 3.5m² cross-sectional area originally had a storage capacity of 875 tons. When the emptying started, it contained 105 m of reef and an estimated 3 800 tons, calculated assuming an estimated 22 m² average cross-sectional area. The ore discharged for 2 hours before it stopped flowing. A concussion bomb was blasted and it ran for another 40 minutes. This process of blasting was continued and ore discharged from this ore pass for a total of 185 minutes. It is still not empty as there is no ventilation flow through it. The rate of discharge was estimated at between 30 and 70 tons per minute. The discharged ore was estimated to be more than 9 000 tons.

Two marker boxes were dropped into the reef pass before the emptying started. One was put in on 33 level and one on 35 level. At that stage it was estimated that the system contained approximately 20 000 tons below 33 level. Three weeks later neither of these markers had emerged despite hoisting 50 000 tons. It is virtually impossible to judge accurately the storage capacity of the rockpasses at Kloof No. 3 Shaft. Only once the new orepass has been commissioned and the old one emptied, will the actual sizes of the reef passes be known.

Conclusion

Rockpass systems are vital for the vertical transport of rock to the shaft bottom. They form an integral and critical part of the mining process, yet little attention is given to the planning, design and operation of the rockpass system. If the planning and design is done correctly at the initial stages of the shaft design, and sufficient capital is invested in the rockpass system, then expensive, hazardous and time-consuming rehabilitation work or replacement of the system can be avoided.