Evaluation of three rock breaker layouts for mechanized block cave mining

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Synopsis

Mechanical rock breakers are used in block caving operations to reduce the size of ore fragments which are too large to pass through grizzlys at the load-haul-dumper tipping points. Several layouts of grizzly, rock breaker and ore pass are possible. The authors evaluated three different layouts at the Premier Mine Division of De Beers Consolidated Mines. The first layout consisted of a 15m surge bin before the breaker, which was located 15 m below the production level. The second layout had a 43 m long surge bin, with the breaker located 43 m below the production level. The third layout did not have a surge bin, the breaker was located on the production level and operated at the tip. The ore throughput, availability and utilisation, delays, costs and operational experience with each system are discussed. It was found that the rock breakers did not represent a bottleneck in the ore transfer system and a surge bin did not significantly improve the production capacity. The mine has decided to make use of rock breakers situated on the production level, breaking rocks at the tip.

Introduction

Block cave mining relies on the tendency of rock to break up into smaller fragments in the draw column as the primary rock breaking mechanism. Traditionally the block caving method was used in ore bodies which were weak and natural fragmentation of the caving ore was fine. In recent times the block caving method has found application in a number of sub-optimal orebodies in which the fragmentation of the ore is coarse. Coarse fragmentation leads to ore hang ups in the drawpoints and blockages of the tipping points. Secondary blasting is usually employed to clear hang ups and to reduce the size of ore fragments so that they are suitable for load-haul-dump (LHD) transportation. The larger fragments transported by the LHDs often require further reduction in size before entering the vertical ore transfer system so that they are suitable for transportation by conveyor belt and to reduce the possibility of hang ups in the ore passes. This may be achieved by employing mechanical rock breakers mounted at the LHD tipping points. The vertical transport system is also required to provide surge capacity between the LHDs and the horizontal transport system. There are several layouts of tip, rock breaker, surge bin and ore-pass that may be employed. This paper presents the results of a study of three rock breaker layouts with the aim to determine which is the most efficient in terms of ore handling capacity and cost.

The study was carried out at the Premier Mine Division of De Beers Consolidated Mines. Premier Mine, which is situated 38 km to the east of Pretoria in South Africa, and has the largest known diamond pipe in the world. It is unique in that, at a depth of 380 m below the surface, it is cut by a dipping gabbro sill, which is 75 m thick. The mine started operating in 1903, first, with open-pit mining and, later, with open benching and grizzly block caving. Open stoping, which was the first method attempted below the sill, failed as a result of premature collapse of the sill and incompetent kimberlite, resulting in major support and drilling problems.

Panel retreat caving has now been in progress in the BA5 mining block below the sill since 1991. A plan showing the layout of the orebody, production level and location of the ore-pass system is shown in Figure 1. Unlike most block caving layouts, the ore passes are located outside the orebody, in stronger country rock. A schematic section through the vertical ore transfer system from the production level to the main transfer conveyor is shown in Figure 2. Ore is transported by load-haul-dumpers from the draw points to the ore-pass system on the 630 level. The ore is either tipped directly onto a grizzly with a rock breaker, or into a surge bin, which feeds to a rock breaker. Rock breakers reduce the over-size rocks so that they can pass through grizzlys at the top of the passes.

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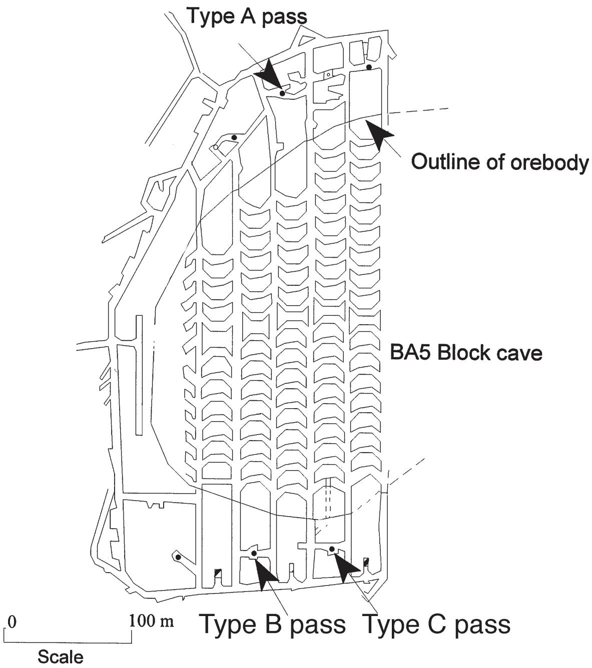

Figure 1—Plan showing layout of BA5 Block Cave and position of passes

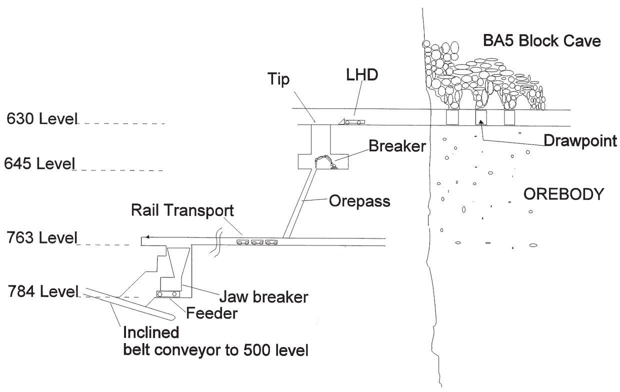

Figure 2—Schematic section showing flow of ore from drawpoints to inclined conveyor

After rail haulage on 763 level, the ore is transferred to an inclined belt system to the main hoisting shaft.

The size distribution of the fragments resulting from caving is difficult to measure and predict, and the mine has made a determined effort to achieve this because fragmentation of the overlying sill and surrounding norite country rock will impact on the production at some stage. Fragmentation of the kimberlite was predicted to be coarse. It was expected that 50 per cent of the blocks taken from the drawpoints would have to be broken further by secondary drilling and blasting before the ore could move through the passes. The coarse fragmentation has forced the mine to undertake extensive secondary blasting, which has rapidly improved both in method and efficiency. The aim of secondary blasting is mainly to reduce the size of the fragments so that they are suitable for LHD-transportation from the drawpoints to the various ore passes. These fragments are usually still too big for belt conveyors and normally cause major hang-up problems in ore passes. For this reason a system of rockbreakers was installed to further reduce rock sizes to pass through grizzlys with minimum dimensions of 30 cm to 70 cm and maximum dimensions of 50 cm to 100 cm. One of the concerns was that the rock breakers would represent a bottleneck in the vertical ore transfer system since a breaker could spend a considerable amount of time breaking a large rock fragment down to a size that would pass through the grizzly. If the grizzly becomes choked during this operation an LHD will not be able to tip at that tipping point. A solution was found in which a surge bin was provided between the LHD tipping point and the breaker by placing the breakers below the production level. The surge bin would, therefore, allow uninterrupted tipping by the LHDs whilst the breaker operated with a continuous flow of rock from the surge bin.

The BA5 block cave was designed so that two LHDs would tip at each ore pass. If there are problems at a particular ore pass, it is possible for an LHD to tip into an adjacent ore pass. At the time of writing the BA5 mining block was producing approximately 2 Mt/a of which approximately 1,7 Mt/a is handled through five vertical ore transfer systems. Three of these systems were selected for comparison, shown in Figure 3. It can be seen that the passes used in the comparison were fed from parts of the cave which were similar in terms of rock type, maturity of cave and fragmentation. The drawpoint availability was good during the period of the study, and ore availability was not a factor in the production rates of the systems.

Rock breaker layouts

Three different layouts of surge bin, grizzly, rockbreaker and ore pass exist among the 5 rockbreaker systems employed. The three layouts are shown in Figure 3.

Features of each system

It can be seen that the Type A system has a surge bin which is 15 m long with a capacity of approximately 189 tons. A sizing grizzly is located on the production level with apertures of 1,5 m by 1,5 m. The function of this grizzly is to prevent over-size blocks, which should have been reduced in size by blasting, from being tipped into the surge bin. The rock breaker is located below the production level. The surge capacity provides a buffer between the periodic dumping of rock at the tip and the breaker. All the layouts allow independent dumping by two LHDs. The Type B system has a much larger surge capacity of 755 tons, the breaker being
43 m below the tip. In the Type C layout the rock breaker is located on the production level, without any surge capacity. The pre-screening at the Type A system allows easier blasting of over-size blocks than at the other two types, because there is no danger of damaging the rock breaker by blasting.

The diameters of the surge bins and ore passes are shown in Figure 3. It can be seen that the diameter of the passes was generally 4 m. A 25 m long section of the pass below the grizzly in the Type A layout was 2,1 m in diameter. These passes were subsequently concrete lined and the finished diameter of the passes was 3m.

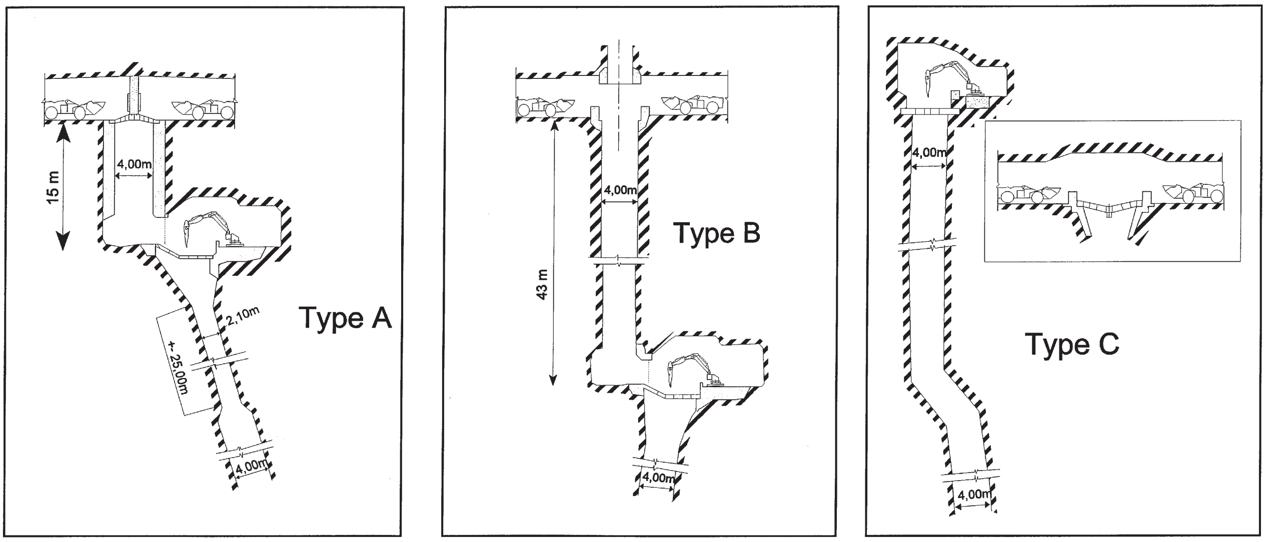

Figure 3—Three rock breaker layouts evaluated

Detail of breakers

The rock breakers used in the three layouts were similar in construction, being fixed breakers with hydraulic hammers on pilot-operated booms. The hammer mass in the Type C system was 825 kg whereas the hammers in the other layouts were 1250 kg. The maximum reach of the breakers was 5,6 m from the centre line of slew and a maximum depth of 4,7 m below the base level.

Detail of grizzlies

The grizzlies used on the layouts were not identical. The details of each grizzly are summarized inTable I. It can be seen that the layouts were fairly similar. The only major differences being that Type A and B grizzlies were mounted lower than the Type C grizzly. The minimum aperture of the Type C grizzly was also larger than the other two types. All the grizzlies were of a type which allowed easy replacement of grizzly bars by slotting them in position without the use of bolts or other holding devices. The Type C grizzly aperture was subsequently reduced to 0,6 m x 0,7 m after a study was completed on hangups and pass wear in this type of ore pass. The orientation of the main bars of the grizzly was parallel to the boom in Types A and B and across the boom in Type C.

Production throughput of each system

The monthly tonnage passed through each system during a one year period is shown in Figures 4 to 6. The Type A-pass shows a fairly consistent tonnage except for the month of January. The other two types produced more erratically. The highly erratic tonnage of the Type B system was mainly the result of hang ups in the ore pass. In terms of the total tonnage passed, the Type A system performed the best, with a throughput of 452 000 tons compared to 426 000 tons and 412 000 tons for Types B and C respectively.

Table I

Detail of grizzlies

Layout	Aperture (m)	Elevation below breaker base (m)	Slope (degrees)
Type A	0,3 x 0,5	1,8	20
Type B	0,3 x 0,6	1,5	20
Type C	0,7 x 0,75	0,5	10

Availability and utilization of breakers

Records of all rock breaker delays, operating time and cause of delays are kept by the rock breaker operators. The records allow a detailed analysis to be done of the availability and utilization of each rock breaker. The availability of the rock breakers within each layout was defined as a function of the servicing schedule and the frequency of breakdowns. The scheduled hours per day for a two-shift operation was 8 hours per shift minus the time taken for scheduled maintenance. The scheduled maintenance was typically half-an-hour to one hour per day. The availability was determined as the total scheduled hours, minus the breakdown hours, over the total scheduled hours. The utilization was calculated as the actual operating hours divided by the available hours. The actual operating hours were determined from the electrical operating hours for each breaker, since the breakers

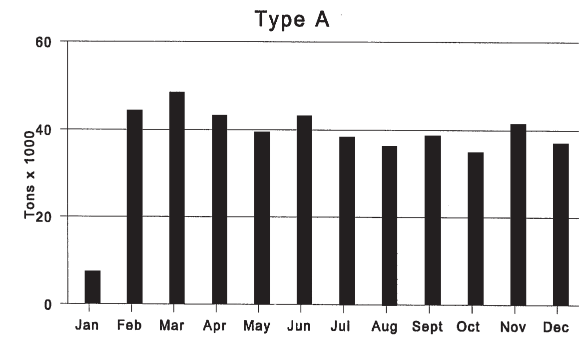

Figure 4—Production throughput of layout A

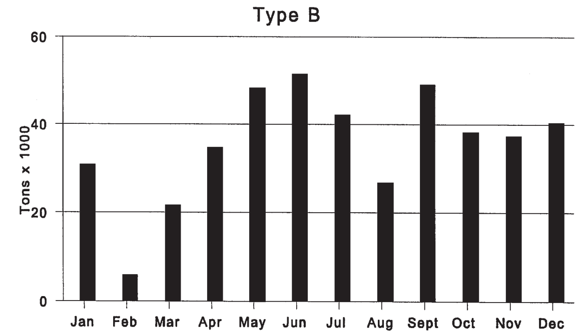

Figure 5—Production throughput of layout B

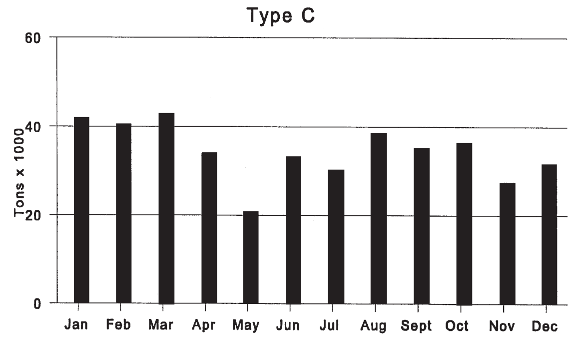

Figure 6—Production throughput of layout C

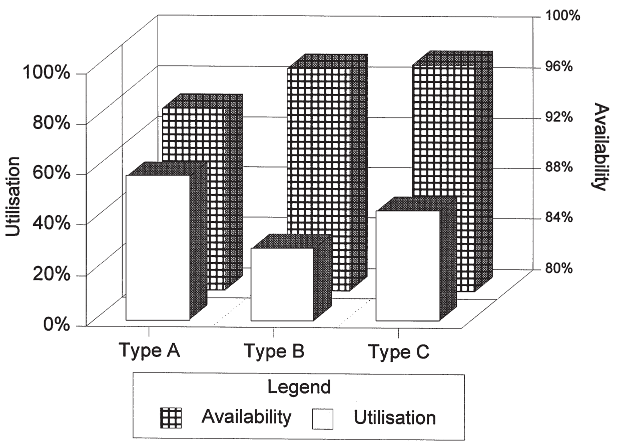

Figure 7—Utilization and availability of ore transfer systems

are turned on only while actually breaking rocks. Figure 7 shows the resulting availability and utilization of the three systems. The availability is high, over 94% in all cases. This implies that breakdown time was in the order of less than 6% for the different systems. The utilization of the systems was between 28% and 56%. The reason for the low utilization is that there is considerable standby time, when the ore flow is good and the breakers are not required to assist rock flow through the grizzly. The low utilization of the Type B pass was due to higher standby time, implying that the rock flow was smoother and the breaker was not required to break large rock fragments as often as the other two systems.

The production rate of the systems, determined by the throughput tons, divided by the utilized hours, shows that

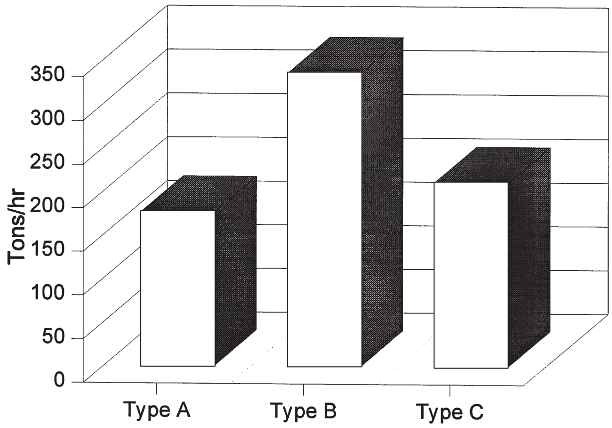

Figure 8—Production rate of the three systems based on utilization of the passes

the Type B system had the greatest production potential (see Figure 8).

Delays experienced by the three systems

The delays experienced by each system may be categorized as follows:

- breakdown delays
- surge bin hang up delays
- ore pass hang up delays.

Figure 9 shows a summary of the delays experienced in each layout in hours per annum. It is clear that breakdowns were the main cause of delays. Hang ups in the surge bin resulted in minor delays in the Type A and Type B systems, while hang ups in the ore passes were the most severe in the Type A and Type B systems. Breakdown delays may be caused by numerous factors—the operator experience and quality of maintenance may be contributing factors. One aspect of the layout that has an effect is the fact that supervision of the breaker in the Type C system is better, because it is located on the production level. It also had the lowest breakdown delays. The high breakdown delays for the Type A system was aggravated by the fact that large rocks often rolled out of the surge bin, hitting the hammer of the breaker while it was operating. This resulted in broken cylinders, hydraulic pipes

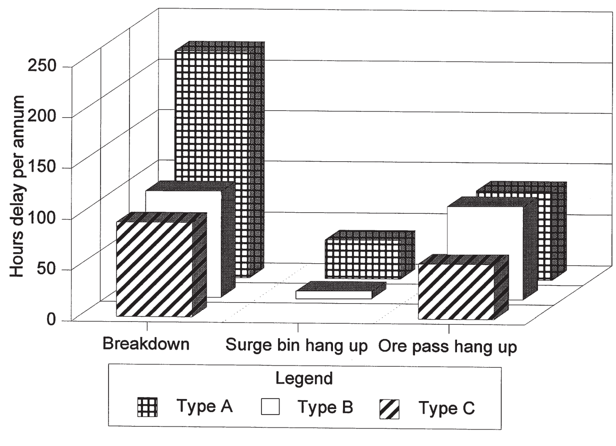

Figure 9—Summary of delays in each system

and bracket pins. Consequently, the Type A system suffered more frequent and more severe breakdown delays. The elevation of the grizzly relative to the operator also contributed to the breakdowns, since the grizzly was lower down than in the other system. The operator had difficulty in seeing the rocks he was breaking and was often unaware of large rocks about to roll out of the surge bin and impacting onto the boom of the breaker. In general the breakdowns were associated with hydraulic pipes bursting, damaged cylinders, broken pins and cracked booms.

The effect of grizzly layout

The grizzlies used in all the layouts were of a type where the grizzly bars slotted into each other. This allowed easy maintenance. The grizzly openings are given in Table I. Two other aspects of the grizzly were found to have an effect on their efficiency. These are described below.

Operator location

In the case of the Type A layout the operator was located in such a position that he could not see the top of the grizzly properly. This resulted in poor operation of the breaker and may have contributed to the high breakdown rate of this system, as discussed.

Inclination of grizzlies at the breaker

The grizzly inclination was not identical in the three layouts. Different configurations were used in an attempt to ensure that the oversize rock fragments would slide towards the breaker. The grizzlies typically had an inclined section to facilitate sliding of fragments and a flat breaking section where the breaker operated.

In layouts A and B the grizzly at the breaker consisted of two sections. Directly below the surge bin the grizzly was inclined at 20° and it was flat towards the breaker, as shown in Figure 1. It was found that the rock did not always slide towards the breaker and it was necessary for the breaker to rake the rock fragments towards itself. The raking activity reduced the breaker efficiency and often resulted in damage to the breaker as large rock fragments rolled uncontrolled out of the surge bin.

In layout C the problems of damage to the breaker did not occur owing to the lack of a surge bin. The grizzly in the type C layout had a 'V' shape with two equal sections dipping at 10° towards the centre of the LHD tipping area. The rocks tend to roll towards the centre of the grizzly, resulting in a concentrated target for the breaker. The concentration of large rocks at the centre of the grizzly left sufficient space around the edges for LHDs to continue tipping if a large rock fragment proved troublesome to break. LHD delays owing to the non-availability of the tip were minimal in this layout.

Operating costs

Operating costs for the three layouts were determined from the labour, maintenance and electricity costs over a period of one year. The cost records were not specific enough to allow the three systems to be evaluated individually. The annual budget figures were therefore used, rather than the actual figures. The relative cost per ton handled by the three systems are shown in Figure 10 where it can be seen that the operating costs were within 4% of each other. There is little to choose between the three layouts from the point of view of operating costs.

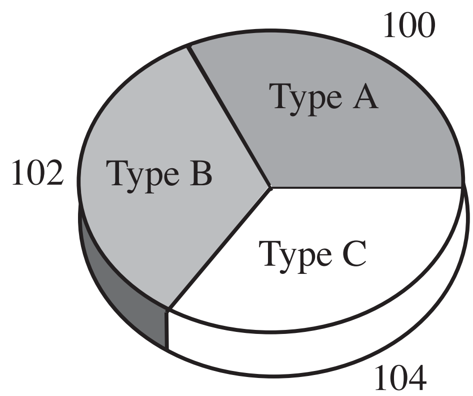

Figure 10—Relative operating cost per ton of the three systems (Type A=100)

Conclusions

It is concluded that:

- ➤ The rock breakers did not represent a bottleneck in the vertical ore transfer system. The additional surge capacity provided by layouts A and B did not result in significant improvements in throughput compared to layout C. The utilization of the breakers is only about 25% of the available time. Most of the time the breakers are merely on standby.
- ➤ Layouts A and B had higher rates of breakdowns compared to layout C, partially owing to the lack of supervision on the breaker level, longer response times to breakdowns, rocks rolling out of the surge bin and damaging the rock breaker hammer and unfavourable grizzly layout requiring that the breaker rakes the rock fragments towards itself.
- ➤ Delays caused by hang ups in the surge bin and ore pass resulted in poor performance in layouts A and B. Layout C also suffered from ore pass hang ups to a lesser extent. The lesser amount of hang ups experienced at pass C may be because it was newer and had suffered less wear than the other two passes.
- ➤ The V-shaped grizzly of the C-layout proved highly successful since it concentrated the rock fragments directly in front of the breaker resulting in more efficient use of the breaker. As a result the breaker did not interfere significantly with the LHD operations.
- ➤ The costs of operating the different breaker systems is similar, and the additional capital cost of providing a breaker level is not warranted by the performance of the layouts A and B.

The mine has decided to make use of the C type layout in its future block cave designs. The V-shaped grizzly, smaller capital requirement, improved supervision and operator visibility clearly outweighs any advantages to be gained by incorporating a surge capacity above the breaker.

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