Rockpasses: a guide to excavation methodology

by U. Sachse* and N. Westgate†

Synopsis

This paper explores a systematic approach for mining decision-makers to use when faced with choosing which method to use for a specific rockpass length. The different excavation methods available in the broad South African mining industry are compared against a number of critical parameters, as applied to rockpasses of varying length. This approach is not meant as a definitive, prescriptive planning tool, but rather as a proposed approach to enable designers and planners to choose the best system to excavate their specific rockpasses.

Alternative rockpass excavation methods

There are numerous alternative methods of excavating rockpasses. In this section the commonly used methods are outlined briefly as a precursor to their comparative evaluation.

Handheld drill and blast

This method involves the simple process in which a rock drill operator and his assistant carry out the following tasks:

enter the pass
climb up to the face by whatever means available, often only a climbing chain
water down
make safe
drill suspension holes
extend the climbing chain, services and ventilation
build a platform
install a safety net
drill the overhand face above
fetch explosives and charge up
remove equipment and platform and leave the workings.

Raise climber drill and blast

This method is essentially the same as that above except that the ladderway or climbing chain has been replaced by a mechanical structure on which a cage is mounted for safe travelling up and down. Transport of tools and equipment is facilitated.

The cage roof is a safe and sturdy platform from which to drill.

Conventional drop raising

Conventional drop raising requires access to the top and bottom of the pass, and excavation and preparation of a site in the raise. It involves the following:

multiple holes are drilled downwards, from the raise to the cross-cut by means of a bar mounted (compressed air) drifter
the hole diameter is generally 50 mm
the drill string is relatively thin and therefore flexible
charging up is done from the raise
blasting is sequential from the bottom up
the length of the box-hole is generally limited to 35 metres, but holes of up to 50 m have been completed
success is also dependent on the holes being as steep as possible.

Unless the drop raise site is off the raise line, raising stops while this process is under way.

Invert drop raising using down-the-hole hammer technology

This method is very similar to conventional drop raising, but the availability of drill rigs using down-the-hole (DTH) hammers, both compressed air and water driven, has led to the drilling of the long holes from the cross-cut up to the raise. Owing to the inherent accuracy and higher penetration rates achieved by using the DTHs, longer holes can be drilled effectively.

Reaming of stab holes to up to 165 mm to enhance the blasting effectiveness is standard practice.

* *Hydro Power Equipment.*

† *AngloGold Ashanti.*

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Raising and development can continue simultaneously.

The water-powered drilling units have pioneered a unique system of slot drilling, whereby a free face is generated across the whole diameter of the rockpass. A system of using multiple hammers is also used to ream a large diameter stab hole. These two methods allow for the pulling of significantly longer rounds.

Blind boring

Boring of longer box-holes, also from the bottom up, has been effectively used since the 1970s. This method has been improved steadily since then to the current position of being generally well understood and applied on a regular basis on mines requiring long passes.

Site excavation, support and civil works for the base make this method onerous and expensive.

Raise boring

The drill rig is erected on top of the required excavation and a pilot hole is drilled through to the discharge point. A reaming bit is then attached and the large diameter rockpass is then reamed back up the hole. This method generally requires extensive site preparation and is suitable only where access constraints are not a factor.

The comparative process

The different excavation methods described above have been categorized and compared as follows:

- The design length of rockpasses is the primary basis of comparison
- Lengths were divided into six 15 metre intervals, ranging from the base case of 15 to 90 m length. In SA underground hard rock mines, rockpasses in excess of 90 metres are not very common
- The six categories are accepted as encompassing the general population of rockpasses excavated in current mining practice
- The suitability of each excavation method for each of the rockpass length categories was then evaluated, taking into account the following key parameters: safety; site preparation requirements; speed of excavation; risk of not achieving an acceptable product; box front, plug and grizzly installation; and overall cost of the final product
- The result of the evaluation is a simple tabulation that the mining engineer can use to compare the length of pass he wishes to excavate with the type of excavation method that may be suitable
- The colour coding of the tables which follow, are subjective and reflect the opinion and experience of the authors (Red = unacceptable, yellow = tolerable, green = favourable)

Safety

The overall consideration is the exposure of persons to risk of injury or death. See Table I.

The following points are relevant with regard to safety:

- as a rule, safety is not relative; either the method is intrinsically safe or else persons are exposed to unacceptable risk
- for this distinction, the method either requires persons to be present in the box-hole or not
- while the authors acknowledge that many handheld box-holes have been excavated without injury, the risk remains high. On this basis, only short boxe holes can be deemed to be tolerable if excavated by handheld methods
- the raise climber method is acknowledged as being significantly lower risk than handheld, but still has persons in the box-hole
- the other methods do not expose persons to the traditional hazards of deep underground mining. However, other more manageable risks remain.

Site preparation

The following questions considered in the preparation of comparative Table III is the site preparation:

- onerous?
- expensive and time consuming?
- difficult to excavate?
- impacting on development?
- involving costly foundations?
- involving support costs?

Table I—Safety

LENGTH	Hand Held	Raise Climber	Drop Raising	Invert Drop Raising	Blind Boring	Raise Boring
15	Doubtful	Yes	Yes	Yes	Yes	Yes
30	No	Yes	Yes	Yes	Yes	Yes
45	No	Yes	Yes	Yes	Yes	Yes
60	No	Yes	Yes	Yes	Yes	Yes
75	No	Yes	Yes	Yes	Yes	Yes
90	No	Yes	Yes	Yes	Yes	Yes

Table II—Site preparation

Metres	Weeks					
	Hand Held	Raise Climber	Drop Raising	Invert Drop Raising	Blind Boring	Raise Boring
15	1	3	1	1	4	4
30	1	3	1	1	4	4
45	1	3	1	1	4	4
60	1	3	1	1	4	4
75	1	3	1	1	4	4
90	1	3	1	1	4	4

Table III—Overall excavation period

Metres	Weeks to Complete Rockpass					
	Hand Held	Raise Climber	Convent Drop Raising	Invert Drop Raising	Blind Boring	Raise Boring
15	3	5	4	2	4	4
30	6	7	7	4	5	5
45	9	9	10	5	6	5
60	12	11	?	6	6	6
75	17	13	n/a	8	7	7
90	23	15	n/a	9	9	7

The following comments are relevant in this case:

- handheld is taken as the base case: typically, one week is required to excavate and support the site
- the raise climber requires a parking bay of about 6 metres before the mast and climber cage can be installed. This rules out its use for holes shorter than 40 metres
- drop raising requires a relatively simple 3 m x 3 m site in the raise
- invert drop raising requires a site equivalent to the handheld method. With this advantage and its quick installation, the method is thus applicable for box-holes of any length. For longer rockpasses, a tapping pass or a dead box layout is used
- the extreme site excavation and support requirements of the blind boring and raise boring systems imply that they have application only to longer passes.

Speed of excavation

A simple calculation has been carried out to compare, for different methods, the overall completion time (in weeks) for a typical rockpass application in that category.

Table III includes the site preparation times from the previous section. The comparative colour-coded rating arrived at is based on the relative acceptability of the total time taken for each category.

Risk of not achieving an acceptable product

The different rockpass excavation methods are compared in relation to the question: 'What is the probability that the end product is unusable?' See Table IV.

The ratings in Table IV were arrived at on a purely subjective basis, in discussion with mining engineers and based on their experiences. As the method used becomes more sophisticated, a higher level of risk is offset by a higher level of supervision and technical expertise.

Box front, plug and grizzly installation

Generally, rockpasses longer than 30 metres now require a second leg (tapping pass) to ensure that the box front is not subjected to direct impact. The handheld method is used here as a base case because it does not require a separate tapping pass. See Table V.

Comments are as follows:

- the 15 m tapping pass is common to all the processes for passes longer than 25 to 30 m

Table IV—Risk of not achieving an acceptable rockpass

Metres	Hand Held	Raise Climber	Convent Drop Raising	Invert Drop Raising	Blind Boring	Raise Boring
15	L	L	L	L	L	L
30	L	L	L	L	L	L
45	M	L	M	L	L	L
60	H	L	H	L	L	L
75	H	L	H	M	M	L
90	H	L	H	M	M	M

Table V—Tapping pass/box front/plug

Metres	Hand Held	Raise Climber	Convent Drop Raising	Invert Drop Raising	Blind Boring	Raise Boring
15	1	1	1	1	3	3
30	1	1	1	1	3	3
45	1	2	2	2	3	3
60	1	2	n/a	2	3	3
75	1	2	n/a	2	3	3
90	1	2	n/a	2	3	3

1 Conventional Boxfront
2 Tapping Pass & Boxfront
3 Tapping Pass, Boxfront & Plug / Wall

raise climbers, blind hole and raise borers require a plug at the intersection with the tapping pass. This is often difficult to achieve, and is dangerous and expensive
depending on the site specific layout, the site excavation is of no further use and needs to be walled off.

Overall cost of the final product

Basic cost calculations have been carried out using industry standard numbers or contracting rates. Due cognizance has been taken of fixed and variable costs (site preparation, tapping pass, box front, plug). This also means that the costs for mechanized methods become more competitive at different lengths. See Table VI and Table VII.

Summary and conclusions

The applicability of the different methods considered for excavation of rockpasses, based on the above factors, is summarized in Table VIII.

The following are the conclusions for various pass lengths.

Short Passes (<15 m)

The *Hand held drill and blast* method should be applied only to the site excavation (a simple drill rig for this purpose is available) and the first 10 m of the pass. Thereafter the safety risk and timing make this method unacceptable.
Raise climber: site preparation and installation time makes this method inappropriate for shorter holes.
Conventional drop raising: this method is applicable, but the extra cost and the interruption of the raise process counts against it.
Invert drop raising is totally applicable due to set-up speed and speed of drilling, enabling this length to be excavated at competitive cost and with minimum disruption to raising process.

Medium Length Passes (15–45 m)

Conventional drop raising and *invert drop raising* are the most effective methods, the invert process being quicker and more cost effective.
Site preparation and cost are factors against raise climbing, blind boring and raise boring methods.

Table VI—Cost of complete rockpass

Metres	Hand Held	Raise Climber	Convent Drop Raising	Invert Drop Raising	Blind Boring	Raise Boring
15	45,000	82,000	60,000	53,000	185,000	194,000
30	83,000	142,000	111,000	98,000	288,000	306,000
45	131,000	247,000	210,000	187,000	392,000	419,000
60	188,000	307,000	n/a	232,000	495,000	531,000
75	251,000	367,000	n/a	277,000	599,000	644,000
90	323,000	427,000	n/a	322,000	702,000	756,000

Table VIII—Summary

Metres	Hand Held	Raise Climber	Convent Drop Raising	Invert Drop Raising	Blind Boring	Raise Boring
15		Time & Cost	Time		Cost	Cost
30	Safety					
45		Cost			Cost	
60			?			Cost
75		Time		?		
90					?	

Table VIII—Cost/metre of complete product

Metres	Hand Held	Raise Climber	Convent Drop Raising	Invert Drop Raising	Blind Boring	Raise Boring
15	2,983	5,450	3,983	3,483	12,300	12,900
30	2,742	4,725	3,742	3,242	9,600	10,200
45	2,911	5,478	4,656	4,156	8,700	9,300
60	3,121	5,108	n/a	3,867	8,250	8,850
75	3,347	4,887	n/a	3,693	7,980	8,580
90	3,581	4,739	n/a	3,578	7,800	8,400

Medium to long passes (45–75 m)

The most effective methods for this range are the *Raise climber* (negatives are persons up the hole and the overall timing) or the *invert drop raise*, which is quicker overall and cost effective.

Long passes (>75 m)

Raise climbers are effective, but persons are exposed to the hazards of box-holing in extreme conditions. Excavation time starts to count against the method, as does cost.

Latest DTH drilling techniques indicate that *invert drop raising* may be applicable to these long passes.

Blind boring is proven technology for this range, but is extremely expensive and onerous site preparation requirements need to be taken into account.

Raise boring is also well known for these lengths, but easily accessible top and bottom sites must be available. Cost and site requirements will be the decision makers.

While the summary in Table VIII gives a sound overview of the applicability of the currently available methods, the ultimate decision will be driven by site-specific requirements and conditions.