Safety in Mines Research Advisory Committee

DRAFT

Final Project Report

Booklet on Design and Operational Aspects of Drawpoints, Tips, Orepasses and Chutes

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Project Number : OTH 303

Date : August 1997

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SIMRAC PROJECT OTH 303

BOOKLET ON DESIGN AND OPERATIONAL ASPECTS OF DRAWPOINTS, TIPS, OREPASSES AND CHUTES

1 INTRODUCTION

This booklet concentrates on design and operational aspects of the mine ore handling systems. Good design and operation results in safe, efficient mining. Poor design and construction leads to more frequent failures and a greater requirement for repair and maintenance, which may expose workers to hazardous conditions.

The following four components of mine ore handling systems are dealt with:

- drawpoints - the location where the ore is drawn or extracted;
- tips - the point at which the ore is tipped into the ore pass;
- ore passes - allow the ore to be transported to lower levels at which it is crushed or loaded for removal from the mine;
- chutes - used to control the flow of ore from the ore passes into an underground crusher, or into trains or skips for removal from the mine.

The booklet is an extract of information from the SIMRAC OTH 303 research project "Investigation into drawpoints, tips, orepasses and chutes". The detailed report on this project provides information obtained from the literature, a study of accident statistics, conclusions drawn from mine visits, and an evaluation of safety aspects associated with the four components. It should be noted that few references specifically on drawpoints, tips and chutes were found in the literature.

2 RECOMMENDED APPROACH TO ACHIEVE THE "RIGHT" DESIGN

Good design promotes good operation and will therefore enhance safety. *Good design of a component can be said to have been achieved when the actual performance of that component in service meets or exceeds the specified performance for both production output and operating life*.

Detailed attention must be given to design, with the aim of achieving the "right design" and avoiding ad hoc design modifications. The recommended method is to use an approach commonly used on large civil engineering projects in which designs are subjected to thorough review by independent review panels. This approach involves:

- detailed specification and documentation of performance requirements. This will detail at least the following:
    - specification of design criteria;
    - required production capacity;
    - characteristics of material to be handled, for example block sizes, block shapes, grading, water conditions;
    - required operating life of the component;
    - planned repair and maintenance intervals;
    - planned repair and maintenance methods;
    - access requirements and facilities for repair and maintenance;
    - operating principles, for example, whether a pass will be controlled or uncontrolled, maximum and minimum levels of rock in the pass, maximum standing times between drawing from the pass, etc. (This will provide information on which proactive drafting of operating, maintenance and safety procedures can be based).

By drawing up detailed specifications in advance of any design work, the identification of potential problems will be well considered and the potential problems well defined.

- Internal review, by a formally constituted knowledgeable internal review panel (minimum of 3 persons), of all stages of the design process, including critical review of the design criteria and performance specification documents. Internal review should take place at regular intervals. Design staff should be required to make formal presentations of their work to the panel.

- External review, by a formally constituted external review panel (minimum of 3 persons), of all stages of the design process, including critical review of the design criteria and performance specification documents. Independent means independent of mine and mining house. Panel members should be chosen on the basis of their expertise and established reputations. External review should take place on specific occasions such as once or twice per year. Appropriate written reports and design documents must be sent to panel members in advance, and project staff will make formal presentations of their work to the panel. A formal written report is required from the panel within two weeks of the review.

- Regular internal and independent auditing during construction and operation to ensure that methods comply with the principles on which the design and operation were based. Formal written audit reports are required.

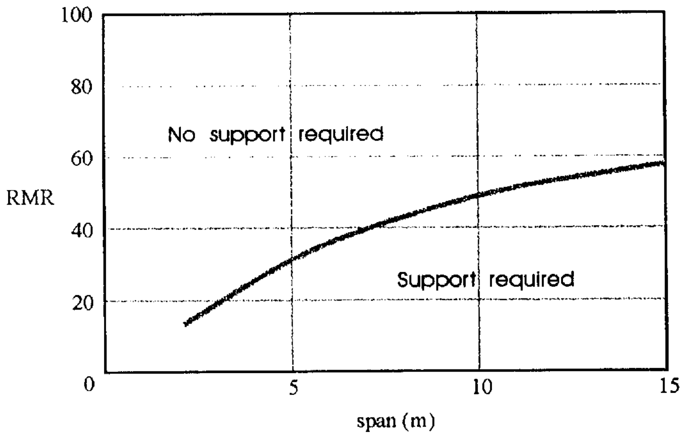
Through internal and external review a broader range of experience is brought to bear on the problem and the likelihood of identifying design deficiencies is greater.

3 DESIGN AND OPERATION GUIDELINES

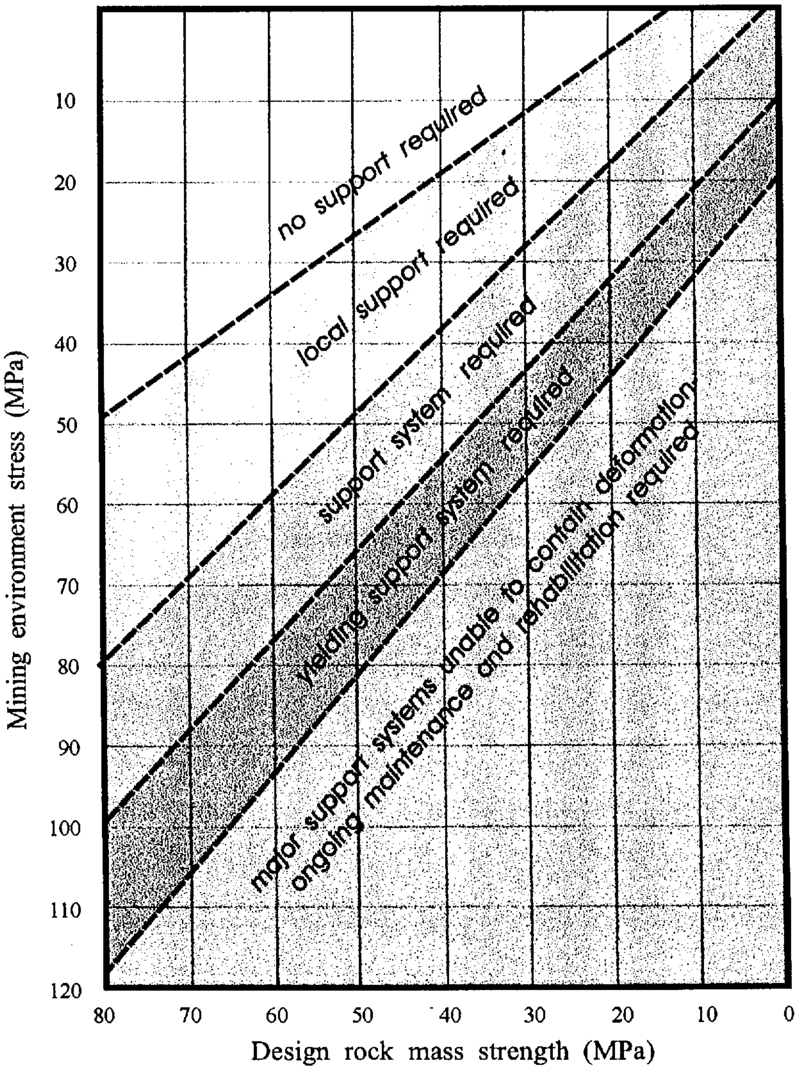
3.1 Drawpoints

The design of drawpoints is part of the overall mine layout design. The size and spacing of drawpoints is dictated to a large extent by the rock mass quality, since this controls the stability of excavations and pillars, and the natural fragmentation of the rock. The rock mass quality can be quantified using rock mass classification methods, Laubscher's method being most commonly applied in mass mining operations.

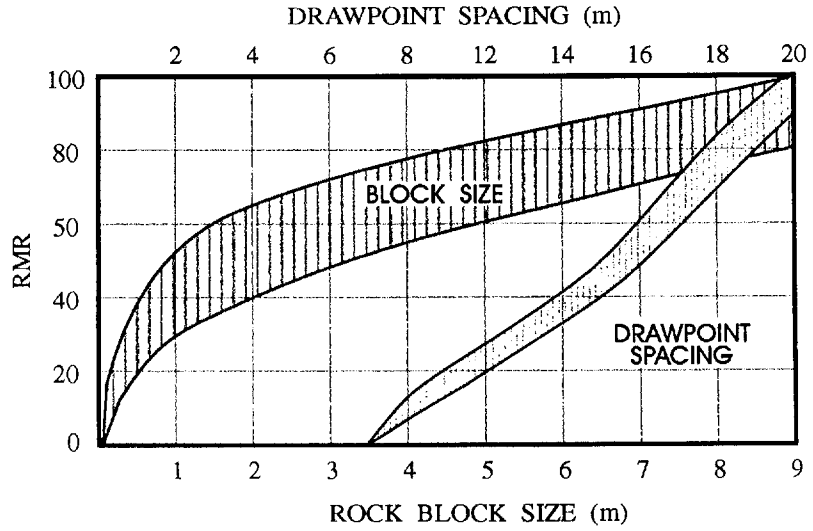
A relationship between the rock mass rating (RMR) value and maximum unsupported span is given in the figure below. This can be used as a guide to determine maximum feasible spans for drawpoints and requirement for support.



Support **which is appropriate to maintain drawpoint stability for the full period of extraction**, and not just to suit conditions at the time of development, must be installed. This will minimise the risk of rockfalls and the requirement for barring down and repair during operation, and hence will improve safety. Drawpoint design is most critical in mines using block caving or panel caving methods. In these methods extraction level development takes place ahead of mining extraction, and the drawpoints are subjected to a range of stresses during their life, including development stresses, point load stresses and relaxation beneath arching in the cave. Support must be designed to cater for all these stress conditions. Drawpoints must also withstand the effects of mechanical action during ore extraction and secondary blasting. The figure below gives a general guide to the required level of support in drawpoints corresponding with the mining environment stress and the design rock mass strength (DRMS). The DRMS is the downrated value of the intact rock strength, taking into account the rock mass quality and other factors such as weathering, blasting and geological structure. As a guide, the DRMS will typically be 30% to 50 % of the intact rock strength. The data in this figure will be conservative for mining methods other than block caving.

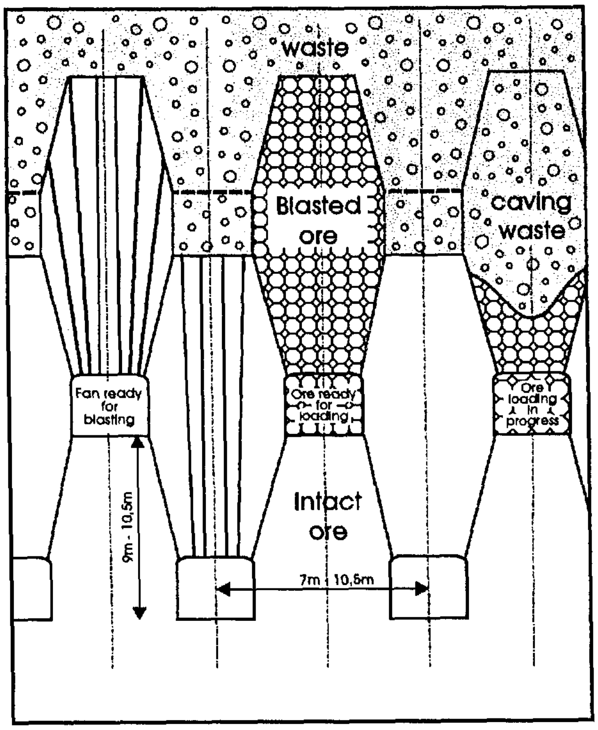


Mine design is very important to achieve the best fragmentation. Fragmentation size is a critical aspect, since it determines the freedom of the draw, the likely frequency of hangups, and hence the requirements for secondary blasting. If the correct design is implemented, hazards associated with drawpoint instability and repair, and with hang-up clearance will be minimised. The figure below provides a guide to drawpoint spacing in block cave mines, and indicates typical fragmentation.



Similar considerations are required for mining methods such as sub-level open stoping and shrinkage stoping, in which the drawpoints, located at the base of the open stope, must serve their purpose throughout the life of the stope. The stability of open stopes is important since failure from the roof and sidewalls of stopes may involve large blocks which cause hangups at the drawpoints.

In mining methods such as sub-level caving and blast hole open stoping, the drilling drives also serve as drawpoints or loading drives. Compared with the drawpoints in block cave mining, the drawpoints are not subjected to the same range in stress conditions, nor require the same life - since the mining face is retreating, the drawpoint "brow" is also retreating, a new "brow" is formed after each blast and the support is required to be effective for a shorter period. In such situations the rock support must be appropriate to maintain rock stability and to withstand mechanical damage. Fragmentation is determined by the blast design and implementation rather than the quality of the rock mass. The design of the layouts must be such that the spacing of adjacent drilling drives provides pillars of adequate integrity, but also allows efficient drilling and blasting. The figure below shows a typical sub-level caving layout.



The following are key design and operating issues for drawpoints:

- design and install support adequate for the design life of the drawpoint, to avoid or minimise rehabilitation requirement;
- minimise point loading and secondary blasting, which cause drawpoint damage, by the following:

  - design mining layouts to minimise oversize fragments (for caving methods);
  - design open stopes to minimise spalling of large fragments;
  - design drillhole lengths and blasts to optimise fragmentation, minimise back damage, minimise oversized fragments;
  - clear drawpoint hang-ups rapidly to avoid point loading stresses. Drill oversize blocks if neccesary and blast (secondary blasting) as soon as possible.
- control draw to minimise development of adverse stresses on drawpoints.

3.2 Tips

Few problems are reported at tips. Three types of tips are common:

- stope tips associated with the use of scrapers, and located in the centre gulleys at their intersections with strike gulleys in narrow reef panel mining operations. They are temporary in that their life is limited to that of the centre gulley. The tips are usually controlled, and have a steel grid over their entrance. Hammers are usually used to break up oversized rocks;
- tips into main passes using rail mounted tramming. Tramming is usually associated with the above, loading material from the stope passes and transferring it to the main tips located in the haulages adjacent to the hoisting shaft. The tips are usually protected by safety barriers, gates or chains, and may contain unidirectional bars or a square steel grid at their top;
- tips in mechanised mining operations, in which material is dumped by LHD or truck. Tipping may take place onto a grizzley to control the maximum size of blocks, and there may be a rock breaker located at the tip to break up oversized blocks. If the passes can accommodate the maximum rock block size, tipping may take place directly into the pass. Bumper blocks are usually, but not always, provided for protection of mechanised equipment. The level of the grizzley may

be raised to floor level to reduce the impact loading. A "dead man box" may also be used to reduce impact damage. If no grizzley is used, the tip ring usually needs to be steel lined to counter wear where the tipping impact takes place.

Key design and operating issues are:

- support the tip area well, with the **correct** support being installed during, not after, excavation - tip areas can be large span excavations which require careful design;
- limit dump height to avoid grizzley damage;
- avoid secondary blasting on tips - remove oversized blocks for secondary blasting in a blasting cubby.

3.3 Passes

Design of passes includes the definition of pass location, orientation, size, shape, length, method of excavation, support, system geometry, and operating principles. Storage capacity and required operating life, may also be important. As identified above, design considerations should be aimed at avoiding problems in the passes.

3.3.1 Problems experienced in passes

Problems are defined as any occurrences which cause the pass to operate at less than the designed performance level.

- **Hang-ups**

  Hang-ups are due to arching of material within the pass, which may have several causes:

  - blocks of rock too large for the size of the pass. These may be the rock blocks which have been tipped or may result from scaling or

collapses from the walls of the pass;
- foreign material entering the pass such as steel supports, rockbolts, timber, and grout flows;
- cohesive arching, which occurs particularly when fine wet material is present ("sticky ore").

Sticky material probably causes the majority of problems in passes and resulting blockages and hang-ups are most difficult to clear. Interaction with other factors such as water, roughness, inclination, bends, compaction etc is relevant. The main effects are:

- compaction of the material occurs when sticky material dries out in the pass;
- compaction of material due to the impact from the fall of the material;
- sticky material may adhere to the sides of the pass, reducing its effective size. This is particularly so at bends and constrictions;
- sticky material can cause small particles to adhere together to form much larger particles. The resulting pass size to particle size ratio may then be adverse for hang-ups.

When sticky material is present the risk of run-aways and mud rushes is greater.

Hang-ups occur commonly in passes. Information from 3600 passes in gold mines shows that 35% were subjected to hang-ups, blockages and runaways.

- **Blockages**

  Blockages usually occur at the chute beneath the pass, where there is a constriction. Blockages can lead to run-aways particularly if water is present.

- **Collapses**

  These may occur within the pass as a result of the geological structure, scaling due to high stresses, and wear of the pass, and can lead to hang-ups and blockages.

- **Scaling**

  When stress exceeds strength, scaling can occur, leading to collapse and subsequently to hang-ups and blockages. Scaling is exacerbated by the passage of rock down the pass.

- **Wear**

  Abrasion of the surfaces of the pass, plucking out of rock blocks from the surfaces of the pass, and impact damage are all included in this category. Wear leads to enlargement of the pass, to collapses and ultimately to hang-ups and blockages.

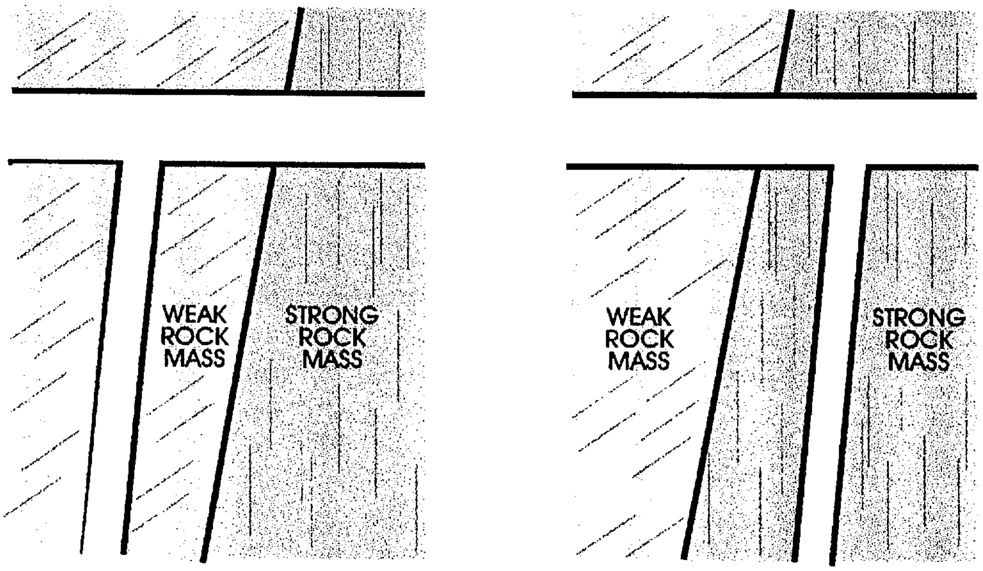
- **Run-aways**

  Run-aways are the uncontrolled flow of the contents of the pass past the control chute, and include mud rushes. They are associated with excess water, and often also with "sticky" material and compaction conditions.

3.3.2 Pass design and operating guidelines

- **Location of passes**

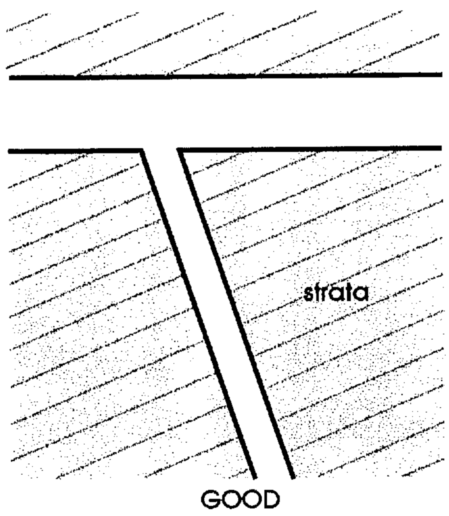
In the mine design process, locations of passes should be chosen to avoid poor rock if possible. If this is not possible, lining may be necessary.

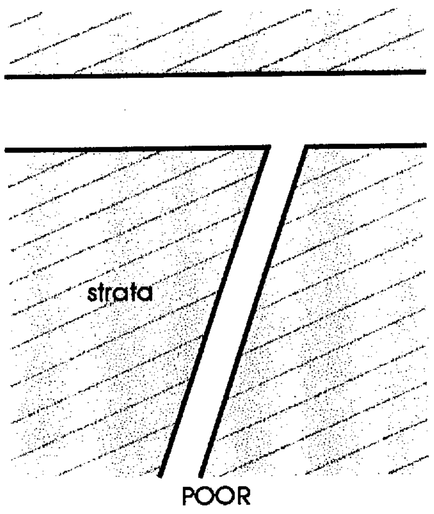


LOCATE PASSES IN STRONGER ROCK MASS

- **Orientation of passes with respect to geological structure**

Failure occurs more readily for some orientations with respect to the geological structure than for others. In stratified rock masses, passes should be orientated to intersect the strata as near to perpendicular as possible.



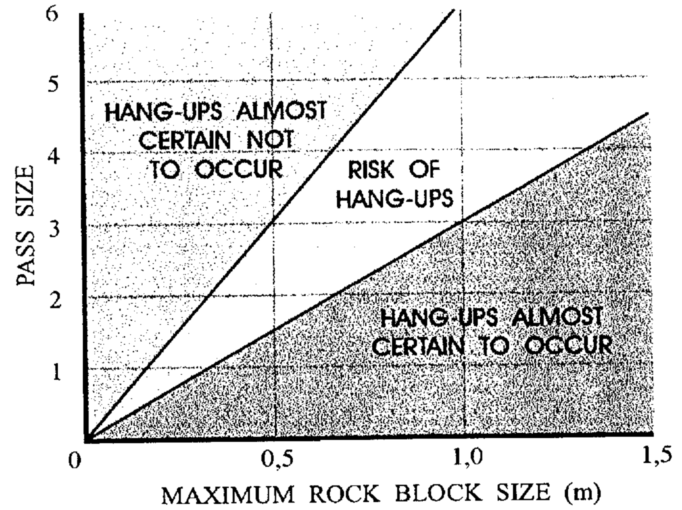


- **Orientation of passes with respect to stress**

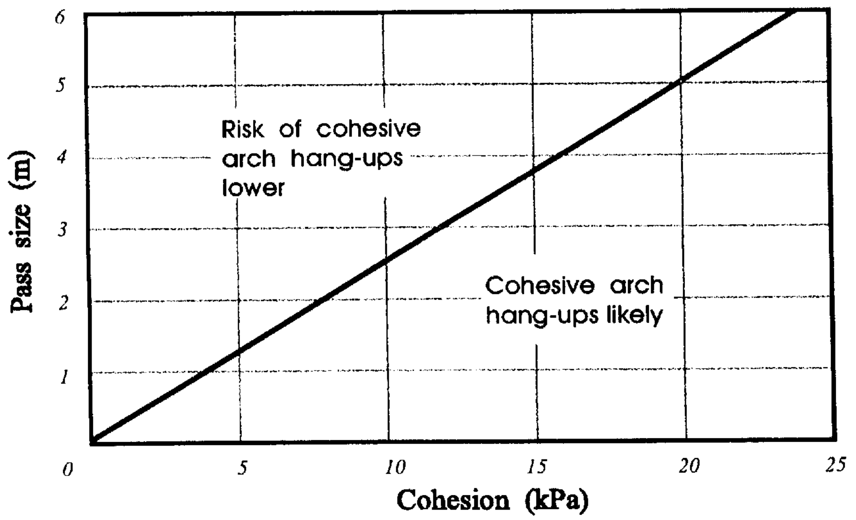
  In high stress conditions, the best pass orientation with respect to the stresses is sub-parallel to the maximum principal stress. If other factors allow, this orientation should be used if it is suitable.

- **Size of pass**

  The risk of hang-ups due to rock arching is a function of the size of the pass with respect to the size of the rock blocks being passed.



If the material being passed contains more than 20% fines, the risk of cohesive arching is present. The size of pass required to cater for this risk is dependent on the value of cohesion as shown in the guideline diagram below.



- **Inclination of pass**

The effects of pass inclination are summarised in the following table.

Parameter	**Steeper Inclination**	**Shallower Inclination**
Velocity of rock	Higher. Rocks bouncing against walls can cause damage	Lower
Impact	High, can cause compaction	Low. Impact for vertical passes can be about 4x that for 50° passes
Wear	Lower. Only impact damage due to velocity	Higher due to sliding of material on footwall
Length	Shorter	Longer for the same vertical interval
Hang-ups	Less likely. High compaction main adverse effect	More likely. Slower movement of ore, accumulation of material (particularly "sticky"), greater length, are main adverse effects

The minimum recommended inclination is 55°, which is applicable for dry ore which flows well. In general, pass inclination should be greater than 60°, and even steeper if wet fines are present.

- **Length of passes**

The longer the pass, the more likely it is to have problems, owing to:

- the greater extent of rock mass traversed
- the greater velocities that material can attain
- the greater difficulty of access to clear a hang-up or blockage and when rehabilitation is required.

Passes with leg lengths of less than 50 m have rarely had problems.

- **Method of excavation**

The comparative effects of boring and drill and blast excavation are given in the table below.

Parameter	**Bored Excavation**	**Drill and Blast Excavation**
Stability	Better, due to smooth cutting action	Worse, due to blast damage, drilling inaccuracy
Flow of rock	Fast - greater compaction and wear	Slower - greater possibility of accumulation of material
Hang-ups	Less likely - compaction is adverse influence	More likely for same size

Footwall roughening of bored passes can overcome the adverse effects, and increases the pass size. Blasted passes tend to be larger than bored passes for the same requirement.

- **Water in passes**

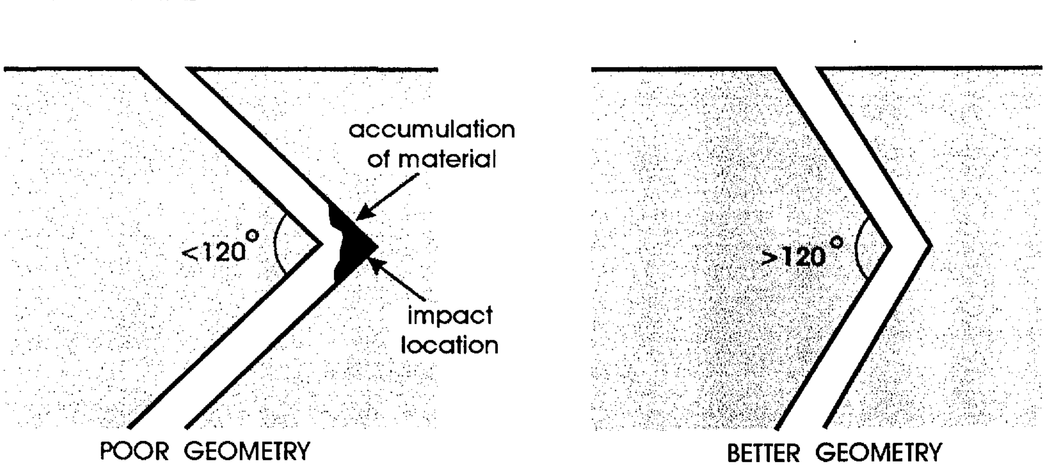
Water entering passes, from whatever source, is adverse:

- formation of sticky ore is likely;
- the risk of hang-ups and mud rushes is increased;
- the flow of rock is affected.

Uncontrolled inflow of water should therefore be prevented. Sealing of passes by grouting may have great benefit to pass operation in the long term.

- **Pass system geometry**

The geometries of bends and branch intersections are important, since they are locations subject to wear, impact, and slowing of material flow, and are therefore more likely locations for hang-ups. Sizes of branches and main passes must ensure that constriction does not occur.



- **Operating methods**

Advantages and disadvantages of controlled and uncontrolled passes are summarised in the following table.

	Controlled Passes	**Uncontrolled Passes**
Advantages	- Confinement by rock material promotes stability - Reduced impact wear - Reduced scaling - Collapses minimised - Impact compaction reduced	- Reduced risk of block arch hang-ups - Reduced risk of sticky ore hang-ups - Access from top down if necessary
Disadvantages	- Hang-up risk due to block arching increased - Hang-up risk due to sticky ore compaction increased - Increased "full pass" hazard when clearing hang-up	- Reduced stability since no confinement - Scaling and collapse risk increased - Impact wear - Impact compaction increased - Damage to box fronts and chutes

To minimise the risk of hang-ups, material should be drawn regularly to keep the rock column moving. This is particularly important if water is present. This will prevent the consolidation of the material in the pass as far as possible.

- **Clearing of hang-ups and blockages**

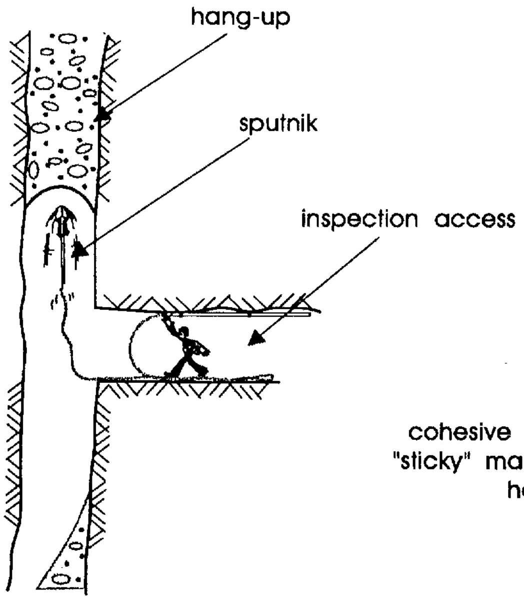
Once the hang-up has been located there are several ways in which it can be cleared:

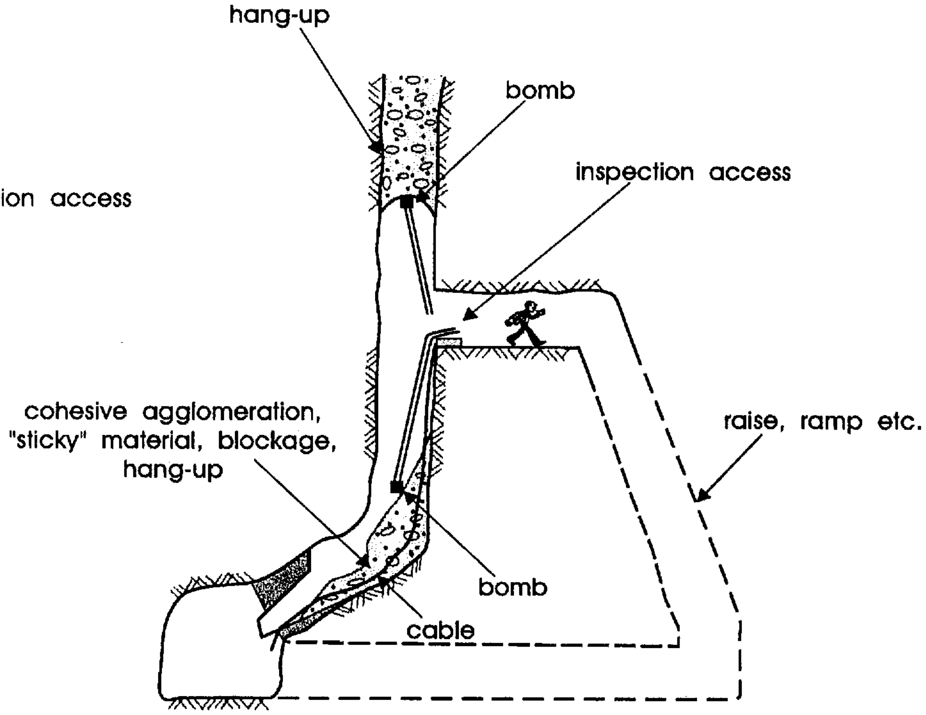
- bombs (explosives) placed in various ways - blasting sticks, balloons, "sputniks";
- slugshots. If the hangup is due to the presence of sticky material, slugshotting may exacerbate the problem;
- boreholes drilled from the top of the pass through the rock material and explosives pulled up against the blockage. This is a high risk method;
- explosives placed through percussion holes drilled from upper or lower levels;
- use of compressed air and water injected through percussion holes drilled from upper or lower levels;
- undermining of sticky ore hang-ups using high pressure water and air.

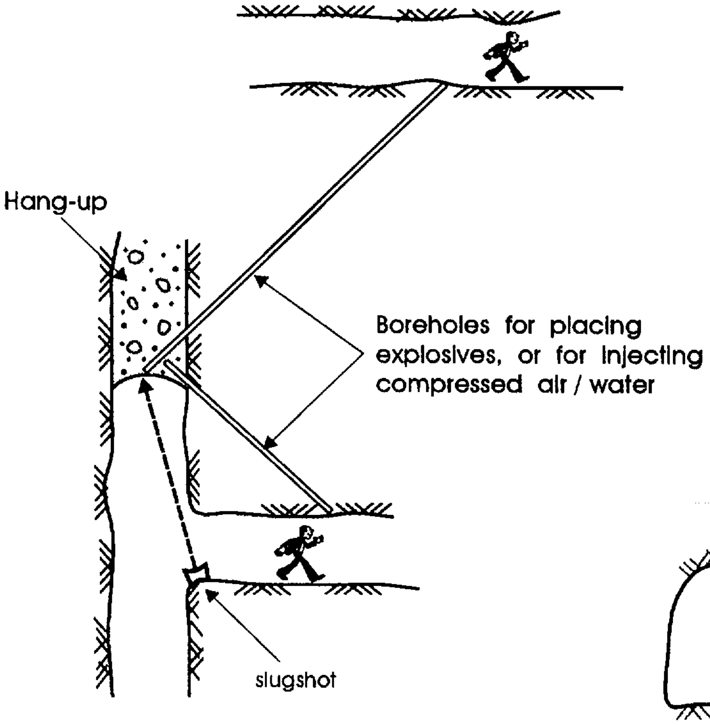
Various methods of clearing hang-ups are illustrated in the attached figures.

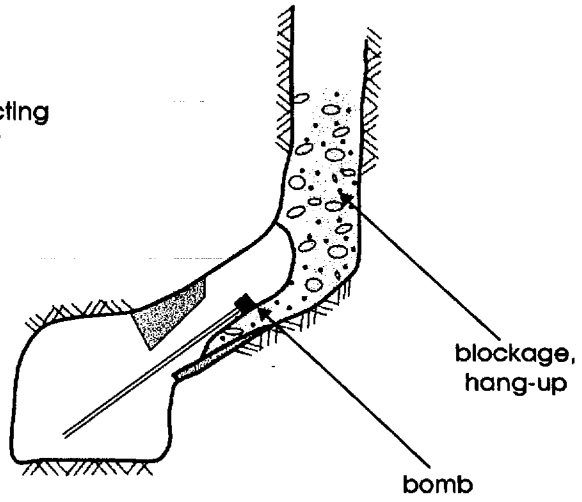
Permanent access points into the pass can be beneficial in clearing hang-ups.

In clearing hang-ups using explosives, it is the concussion that is usually relied on to loosen the hang-up. The use of explosives may damage the walls of the pass, which can produce geometry changes or roughnesses which can be the nuclei for


hang-up
sputnik
inspection access


hang-up
bomb
inspection access
cohesive agglomeration, "sticky" material, blockage, hang-up
raise, ramp etc.
bomb
cable


Hang-up
Boreholes for placing explosives, or for injecting compressed air / water
slugshot


blockage, hang-up
bomb

further hang-ups.

The use of water in passes can be dangerous since it may lead to mudrushes, and must therefore be carefully controlled.

- **Support of passes**

Support is not usually installed in passes. However, the risk of deterioration of passes, hang-ups and blockages may be reduced by implementing support - rock reinforcement, shotcrete, concrete or steel lining, or a combination of these measures. The requirement for support is a specific design consideration, which cannot be addressed adequately in this handbook. In summary, it will depend on:

- geotechnical factors: rock mass quality, geological structure, in situ stresses, stress changes, rock material strength;
- construction factors: method of excavation, size, shape and inclination;
- planning factors: desired life, tonnage to be handled, strategic importance, time between excavation and usage.

Rockbolt reinforcement has been used frequently, but not with much success. In blocky rock and scaling rock situations, wear of the pass causes the rock in between the bolts to fall out. Conventional rigid rockbolts are usually inappropriate, since rock impact causes vibrations in the bolt which destroys the bonding of the bolt. Fibreglass bolts and wire rope reinforcement do not have the same disadvantages. Rock reinforcement should be installed in upwards inclined holes so that any impact from material flowing down the pass does not contact the support at an acute angle.

In weak rock, or in fissile, scaling or closely jointed blocky rock, a lining may be the only way of supporting the rock and preventing uncontrolled growth in the size of the pass. When wear is a problem, special types of lining have been used such as corundum and andesite lava based shotcretes and concretes, and steel fibre reinforced concrete. In non-vertical passes, a greater thickness of lining on the footwall, to accommodate wear, increases the life and stability of the pass.

Precast concrete pipes, both in full circle form and as segments, have been used successfully for lining of passes. Steel liners, in the form of complete "tubes", as steel rails set in concrete, or as a combination of both, have also been used.

“Support” and steel items in particular are "foreign material" which, when worn and loosened, can be the cause of hang-ups.

- **Rehabilitation of failed passes**

Pass rehabilitation options include:

- obtain access and install support;
- install a steel tube or concrete pipe and backfill around this with concrete and waste rock;
- fill pass cavity with concrete and waste rock, and rebore the pass through this concrete;
- grout the material blocking the pass and rebore a hole through the grouted mass;
- replace the pass by reboring or redeveloping a new pass.

3.4 Chutes

Chutes represent constrictions in the rock flow system, and therefore design to ensure free flow and to minimise adherence of sticky material is important. Little is available in the literature regarding design of chutes, however. Chute blockages are very common in

South African mines, and in the research study, chute design was identified as a prime area for improvement. The following are pointers regarding design and operating aspects:

- from the literature, the recommended chute width W is 3 times the maximum rock block size being passed;
- the recommended chute height is 0,8W
- the recommended chute angle is 45° to promote free flow;
- "sticky" material is a very common cause of chute blockages;
- "designed-in" systems for clearing blockages, such as water and compressed air pipes, and access points for use of a pinch bar can be beneficial;
- water should not be allowed to accumulate behind the chute. The design should allow for water to bypass the chute;
- in the case of bigger chutes, physical access to the back of the chute can be beneficial;
- the use of blasting to clear blockages should be avoided if possible;
- some material should be retained in the chutes to provide a cushion against damage from impact of rocks falling down the pass;
- chutes should be drawn regularly, particularly if sticky material is present, to minimise the risk of blockages.

4 CONCLUSION

The guidelines contained in this booklet are intended for making quick assessments. Some of the recommendations may be inappropriate in specific cases. The guidelines do not replace thorough design considerations, and it is essential that the detailed design process recommended in Section 2 is followed.