CONTROL OF ROCKFALL RISKS

Mining Methods and Rockfall Risks

The selection of a mining method is largely a function of the geometry of the orebody and the geomechanical environment. Mining methods can be classified as either 'entry' or 'non-entry' extraction sequences. In entry methods such as cut and fill, shrinkage and room and pillar, the mine production activities, drilling, blasting, mucking, etc., are all performed from within the stopes.

In general, entry-mining methods have lower productivity, exceptions to this rule include rich, narrow vein deposits, often extracted using some form of handheld mining technique and flatlying orebodies mainly mined by room and pillar methods.

Non-entry mining, which includes variations of open stope and cave mining methods, are in general less labour intensive and do not allow personnel to enter the stopes. All production activities, such as drilling, blasting and mucking, are performed from the stope's periphery. This provides an opportunity to secure the ground prior to the commencement of production in areas surrounding the mining blocks, instead of having to repeat the support process during production cycle, as is the case in entry mining. Open stope mining also facilitates the use of remote control equipment as most activities are confined to specific areas, draw points, drilling drives, etc.

Although it could be inferred that non-entry methods have a reduced risk of rockfalls compared to entry methods, the conclusion can only be drawn based on how well the risk of rockfalls is managed at each mine site, regardless of the mining method employed. In general, the more underground workers exposed to areas of a higher probability of rockfalls, the higher the rockfall risk. A wide range of variables applicable to all mining methods may impact on the likelihood of rockfalls and the exposure of personnel. For example, methods relying on intense development mining and low mechanisation will have many workers carrying out tasks at the mine face, an area of higher probability of rockfalls, on a near continuous basis.

Methods relying on large blasts may generate more blast vibrations and localised damage as well as larger instantaneous stress and energy changes. On the other hand, the drilling, charging and mucking operations are generally more efficient and often performed using large and well-protected drill-rigs and mobile equipment including trucks, load haul dump units and others.

Methods requiring large openings may also cause greater stress changes, while the large spans may create greater potential for large rockfalls to occur. These can contribute to increasing the overall probability and severity of rockfalls. This may be compensated by increased mechanisation, where most activities are confined to a smaller number of well-secured areas, resulting in a reduction in personnel exposure.
Mining methods using backfill may offer better regional control of stope closure (lower convergence of hangingwall to footwall) and fewer large voids left open at any time, or for a long period of time. Mine fill can control the risk of uncontrolled collapses and unwanted caving or subsidence. There have been a number of well-documented cases where fill was not used and crown pillars have failed up to surface with a variety of consequences.

The use of mine fill also allows greater flexibility in the extraction sequence and often results in increased or complete recovery of orebodies. The location of voids (stopes in production) and pillars can be strategically controlled to minimise stress-induced problems. In many ways, mine fill can reduce potential sources of instability and the likelihood of a rockfall occurring.

However, other risks associated with fill operations need to be considered. Hydraulic fill in large stopes can introduce the risk of bulkhead failure and flooding. Dry fill reticulated with mobile equipment will increase underground traffic and the risks associated with it.

The selection of mine equipment can also influence the likelihood of rockfalls. Large equipment requires suitably sized excavations that may be prone to substantial falls of ground. High excavations can also be more difficult to manage in terms of scaling, visual identification of structures, loose material, etc. The equipment itself can provide a degree of protection against small rockfalls, with enclosed cabs, Rollover Protective Structure (ROPs) or Falling Object Protective Structure (FOPs).

The level of mechanisation and automation of mining equipment can also reduce the exposure of personnel to rockfalls. For example, mechanised bolting machines minimise the need for operators to spend time at the mine face, outside the cab.

Tasks such as drilling, mucking or charging are commonly done by remote control equipment, while tele-remote and even fully automated mining equipment is gradually gaining acceptance in the industry. These emerging technologies all contribute to removing mine operators from the areas most at risk. However, new technologies may introduce new risks such as people being struck and injured by remotely controlled equipment.

The selection of mining methods and associated parameters will influence the likelihood of rockfalls and the exposure of the workforce. The risk of rockfalls is however a function of how well the hazard is mitigated and managed.

Mining Infrastructure and Access Layout

The stability of mine infrastructure is time dependant. Almost every hole in the ground will eventually close. The closure rate can be extremely fast (seconds) or extremely slow (millions of years).

For a given stress condition, the rate of closure is a function of the rock mass quality. Although there is limited flexibility in the selection of locations for the different components of the mine infrastructure, having a good geomechanical model will provide the knowledge that can help mine planners to locate the infrastructure in the more competent rock masses and as much as possible, away from major discontinuities.

The stability of underground openings can also be influenced by a number of in-situ factors, for example, earthquakes, tectonic activities or ground water, while others are induced by mining activities. The close proximity of mine infrastructure and accesses to the stoping areas (or caving fronts) will reduce mine development and transportation costs but will increase the level of blast vibration and stress changes acting on the infrastructure, thereby increasing the likelihood of rockfalls. Ground control measures may sometimes compensate for the close proximity of the infrastructure but in such cases, the financial gain must be weighed against the increased risk. It is common for mine infrastructure, located relatively close to stopes, to be submitted to one or more cycles of stress increase and stress decrease. The stress increase will contribute to create new cracks and induce slipping along joints followed by a stress decrease, resulting in a general loosening of the rock mass. In such cases, the ground support design must be flexible and account for stress change cycle(s) and elevated blast vibrations. The ground support itself may have time-dependent behaviour, especially if the environment is corrosive. The use of hydraulic fill can also expose ground support in the vicinity of the stope being filled, to a period of intense corrosiveness. All these factors need to be accounted for at the design stage.

Production management and mine planners can sometimes increase the flexibility of their operation by having the infrastructure developed well ahead of time. This is particularly attractive for mines enjoying a surplus in developing infrastructure capability. This strategy is not so desirable however, where an excavation's closure rate is rapid due to weak rock masses or high stress conditions, or if it results in exposing the infrastructure to an increased number of stress change cycles. Therefore, in addition to the normal excavation design considerations (size, shape, orientation, ground support), mine infrastructure design, including ground support, must account for its location relative to stoping activities and the expected service life of the excavations. The timing of developing the infrastructure also becomes critical where rapid closure rates exist.

Mining Sequence

The mining sequence determines the order each stope and mining block will be extracted. Economically, the extraction sequence will often prioritise the stopes having the best combination of high grade and low cost, to maximise the Net Present Value (NPV) of the operation. However, the following objectives are also met:

- Target production rate is maintained or exceeded.
- Stability of the infrastructure is maintained (shafts, orepasses, declines, major accesses, conveyor drives, crusher station, etc.).
- Ore reserves are not sterilised.

Consequently, rock mechanics and stress management strategies may overrule the grade and cost considerations in developing the mining sequence, especially when operating in a high stress environment. Extraction sequences should be designed to account for the following general rules as far as is practicable:

- Mining direction should advance towards solid ground rather than towards active or previously extracted areas.
- Mining should retreat away from potentially ‘unstable’ geological structures.
- When a mining front approaches a potentially ‘unstable’ structure, it should ideally be developed perpendicular to the structure. If this is not possible, an angle of at least 30 degrees between the advancing front and the structure should be maintained.

Reference:
Minerals Council of Australia, Management of Rockfall Risks in Underground Metalliferous Mines.