

5 Operational constraints of temporary and face area support systems

5.1 Introduction

As mentioned in Chapter 2, an adequate areal coverage and an improvement in support performance, such as prevention of toppling, etc., are required to enhance the performance of individual support units in the immediate face area (e.g. see Jager and Roberts, 1986). There are other non rock-engineering parameters that are particularly important to the successful implementation of strata control measures, but little attention has been focused on identifying them and providing solutions. If these constraints (such as time limitation, production pressures, unavailability of labour, inadequate material transport route, etc.) can be reduced such that support units are placed as recommended in the code of practice, then the fall of ground accidents and damage due to rockbursts would be significantly reduced. In the discussion that follows, operational constraints that impose limitations on the successful implementation of rock engineering support strategies in the immediate face area are identified and discussed.

5.2 Operational constraints applicable to temporary supports

Several consultations with production personnel, rock engineering departments, and safety departments were held and underground visits were made to gold and platinum mines with the view to identifying the constraints with respect to temporary support practices. The effect of these on three operational activities, (i) drilling and charging, (ii) blasting, and (iii) cleaning, are considered and presented below.

5.2.1 Drilling and charging

The drilling and charging part of the mining cycle involves all activities between when the morning shift enters the stope and when charging operations are completed. These activities are primarily early morning examination of the panels, barring and making safe, cleaning the barred rocks, installation of appropriate temporary support, marking of shot holes, drilling and charging.

5.2.1.1 Labour availability

With the current stope bonus system adopted by most mines, reward for productivity is directly linked to the face length, linear face advance achieved per month and the number of workers involved. The greater the number of workers per panel, the smaller the bonus each member of the crew receives, as the productivity per man decreases. This means that crews are assigned to specific panels and are not easily moved from one stope to the other during a production month.

The consequence of the above practice, in the opinion of most production personnel interviewed, is that should a member or members of a crew be absent, there is no replacement for them. All the tasks, including the making safe, cleaning of barred rock, supporting, drilling and charging-up operations, will have to be performed in a full shift to ensure a blast. As a consequence, not enough time is available for temporary support installation, particularly with respect to spacing and correct angle of installation. Since there are less workers than normal, temporary support units are spaced wider than specified in the code of practice and therefore

heavy loads are imposed on the few units installed and area coverage is reduced. There is also the tendency for support units to be installed on loose pieces of rock on the footwall (insufficient cleaning of barred loose rock) and as a result toppling of support units is common under these circumstances.

Since temporary support types currently in use rely on human effort for transportation and installation, their proper installation is affected by shortage of labour. Those support units that are heavier to handle and difficult to install, such as hydraulic props (refer to Figure 5.2.1), are the most poorly installed whenever there is shortage of labour, even though they do not have to be transported by hand into the stope.

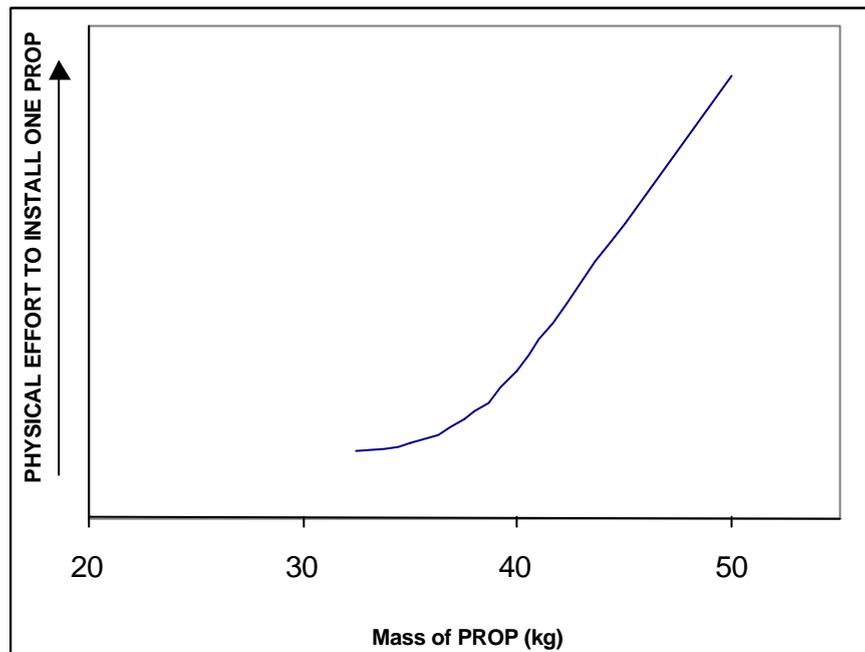


Figure 5.2.1 *The effect of prop mass on the physical effort to install a prop (modified after Van Rensburg et al., 1991).*

5.2.1.2 Time constraints

In order not to expose workers to fumes from blasting, specific times have been set for workers at various stoping horizons to exit the stopes for blasting to take place. This, coupled with the fact that most mines work a three-shift cycle per day, has defined working hours per shift to about eight hours. From time and motion studies conducted on four mines, only a little over 4,5 hours of this time is used in the stope face for making safe, cleaning of barred loose rocks, temporary support installation, drilling and charging-up operations. These 4,5 hours may not be sufficient for a 30 m panel to be drilled and charged-up. Therefore, temporary support is often installed concurrently with drilling to ensure that the drilling and charging operations are completed before the end of the shift. This means that the top portion of the panel, which is often the first to be cleaned, is marked and a few support units installed for the machine operator to start drilling. At the same time cleaning and other activities occur in the middle and lower portions of the panel under an unsupported roof. These few temporary support units are moved and installed at subsequent positions of drilling down the panel. The consequence of this is that some operations, such as marking of the face and charging-up, are done under an unsupported roof and the few mobile units are prone to failure in case of rockfall or rockburst situations.

The support types most vulnerable to the above practice are the extendable types, such as mechanical props. This is because a unit can be removed and re-installed by either retracting or extending its length. The reverse is true for temporary support types such as mine poles which, when installed at a position, will not be possible to re-install at another position with a different stoping width.

5.2.1.3 Availability of support units

The availability of sufficient numbers of support units is vital for the proper spacing of support units in the immediate face area. It was revealed during the underground visits that shortage of support units was common and in most instances insufficient support had been installed as a result.

Hydraulic props, which need regular maintenance and are difficult to handle, are frequently associated with shortages in the stopes. Kloof gold mine is moving away from the use of hydraulic props, partly due to support unit wastage and losses. The consumption rate for support units, such as mine poles, which are mostly blasted out and need to be replaced during the next shift, is high and, therefore, should there be a break in supply, incorrect support spacing is a consequence. There is also the tendency for workers to install support units which would in a normal situation be discarded.

Mechanical props are comparatively light in weight, removable and re-usable, and more often than not available in sufficient quantities in the stope for installation.

5.2.1.4 Transport mechanism and in-stope storage facilities for support units

Inadequate material transport routes and frequent mono-winch breakdowns (or absence thereof) affect the delivery of support units to the stope face and subsequently, the quality of support installed in the immediate stope face area.

Storage facilities for temporary support units, especially in backfilled stopes, has been found to be inadequate and in some circumstances stored support units are cleaned out by scraping operations. In a particular backfilled panel, Ebenhaeser support units were transported to the stope during every shift (as and when required), as there was no place to store them.

5.2.1.5 Stope width

It was the collective opinion of the rock mechanics and production personnel interviewed that the handling of heavy support units is difficult in narrow stoping width conditions (< 1 m). Worker movement is restricted and the ease and accuracy with which support units are installed is reduced. The use of tendons in the immediate face area in most mines has been limited by stoping widths less than 1,2 m (example Vaal Reefs, Beatrix Mine, etc.)

In very high stoping width situations, the practical use of hydraulic props is limited by their weight, as handling is difficult and individual props become a safety hazard by toppling before installation. The blast out rate and buckling potential is also high.

5.2.1.6 Dip of reef

As the dip of reef increases, so does the difficulty in handling and installing support. A consequence of this is that support units are often not stable and tend to topple. Off-centre loading on units is also a common feature. The tendency for workers to hold onto them in ascending and descending the panel is high, thus increasing their fall out rate. Non-

prestressable temporary support units have been found to be the most sensitive to the dip of reef.

In flat dipping stopes, the transportation of support units to the stope face becomes difficult and this is aggravated if the stoping width is narrow as well. As a consequence of transportation difficulties, more time is spent moving support units and consequently less time is available to install a sufficient number of support units.

5.2.1.7 Effect of mine geometry

The shape of mining excavations can have an adverse effect on rock conditions. For example, out of shape stope faces produce additional unfavourably oriented stress fractures, which further add to the burden of the support. A common problem in this regard is when panels above and below a panel have difficulties in achieving the required rate of face advance. This will result in the affected panels lagging behind. When the lagging panel is far behind the advanced panels (generally greater than 8 m), fractures parallel to the sidings of the advanced panels develop in the ground to be mined by the lagging panel. These fractures will be at right angles to the advancing stope face and, in combination with the face parallel stress induced fractures, will form blocky ground which is difficult to support.

Advance strike gullies are developed more than 2 m ahead of the stope face in high stress conditions. In this situation stress fractures curl around the gully in onion ring fashion and intersect the stope as it advances. The fracturing is unsafe and difficult to support. Thus, advance headings should, if possible, be avoided.

Incorrectly shaped faces are practices that lead to the perception that fewer support units need to be installed. In some instances, this has been found to be deliberate so that workers only have to install a minimum number of support units as compared to a straight face where a whole line of support needs to be installed before blasting can take place. Incorrectly shaped stope faces result in non-uniform loading of support units.

5.2.1.8 Position of marked shot holes

A reduction in support spacing in the immediate face area creates interference with other activities, particularly drilling. In practice, occasions do arise when either the support will have to be moved to a position where it does not interfere with the drilling process, or, alternatively, the drilling process will be compromised either by changing the drill angle or shifting the collaring position. In the first case the action compromises the support system, while in the latter it compromises the blasting pattern. This problem is greatly reduced by offsetting rows of support such that the support units are aligned parallel to the drilling direction.

5.2.2 Blasting

Blast-on face and temporary support systems are affected by blasting. Examples of blast-on face support systems are mine poles, hydraulic props, pre-stressed elongates, etc. Among the reasons for using blast-on temporary support is to ensure support of the roof at all times, including during the night shift. Unfortunately, the blast-out rate of these types of support units is very high, especially with units like mine poles, which are not pre-stressed (not hydraulic props or pre-stressed elongates). It was found during the visits that the direction of shot holes and the charging-up process were often not according to standard, resulting in the temporary support units being blasted out. The same might be true for the high incidence of lost rockbolt tension currently being experienced in stopes employing rockbolting at the immediate face area.

Incorrectly drilled shot holes and over-charging could alter the stoping width and induce intense blast induced fracturing in the hangingwall, which would negatively affect the placement of temporary support in the subsequent shift.

5.2.3 Cleaning operation

Scrapers and/or high-pressure water jets are commonly used to clean broken rock from the stope face after the blast. Depending on the straightness of the face, the scraper scoop or rope can damage temporary support units. The overall effect is the downgrading of the support quality, as well as slowing the cleaning process. Broken rock left lying on the footwall also interferes with support installation, as it creates a cushion between the rock surface and the support.

Most codes of practices on the mines stipulate that workers must work under supported roof at all times but this is impossible with the current scraper cleaning method and the columnar support types being used on the mines. This means that before a night shift worker rigs a scraper rope for cleaning purposes (note that in most cases night shift workers are exposed to wide spans of unsupported panels), he has to install some temporary support. However, the non-availability of support units at times on night shift has resulted in non-compliance. From the writer's own knowledge, a team leader was fatally injured on night shift when the roof of the stope collapsed while he was installing a snatchblock. The support to face distance was 4,5 m. The probable reason was that there was no temporary support available anywhere near the panel to install prior to the accident.

5.2.4 Other constraints

The role of human behaviour in accidents in the mining industry has surfaced consistently in recent industry studies. Human behaviour was also mentioned here as an underlying cause of poor support practices. Worker motivation is considered to be vital to successful support practices.

Another fact to consider is that, as mining depth increases, the influence of geotechnical features on the stope environment increases commensurately. Depth is the most important criterion because of seismicity and rockbursts, increasing the need for greater support resistance, higher energy absorption capacity and better areal coverage. Greater support resistance is provided by introducing stronger and generally heavier support systems and reduced support spacing. The aggregate effect of these changes is an increased work load, and, when depth is compounded by other geological conditions such as soft or friable hangingwall or footwall rock types, the effort required is further increased. The consequence of this is poor temporary support practices.

High levels of temperature and humidity affect the quality with which temporary supports are installed and removed. Because stoping practices require temporary support systems to be installed and removed in a prescribed pattern, the capacity of workers to perform both physically and mentally is an important consideration, not to mention the degree of skills and training required.

5.3 Solutions to overcome operational constraints applicable to temporary and face area support systems

5.3.1 Drilling and charging

Solutions to overcome the operational constraints associated with temporary support practices during the drilling and charging-up operations are given below.

5.3.1.1 Labour availability

The current bonus system on most mines, where workers are assigned to specific panels and are not moved around during the production month, should be changed. It is considered beneficial to have a 'floating gang' of approximately three workers per each three crews whose duty will be to assist in panels where support complement falls short on a day. On days in which the support crew of the panels they service are all present, they can assist in other ancillary support activities like support transport, reclamation, etc. That is, their work will be to assist in support related activities only. The bonus system should be designed in such a way as to incorporate the floating gang. It has been established that the absence of two support crew members per shift can result in lost production because not enough support can be installed. Assuming a 30 m panel with an average grade of 6 g/t (1 m advance, 1 m stoping width) will yield 486 grams of gold which is priced at \$280/oz, this would yield a revenue of R 28 800 for the mine for that day, which would otherwise have been lost. The quality of support installed will also be improved.

The practice whereby the installation of temporary support is the duty of only some members of the crew could be changed for every member of the crew to be trained in support installation and should be done by all before operations such as face marking and drilling commences. This practice will ensure that sufficient workers will always install temporary support in the correct procedure and manner.

5.3.1.2 Time

Bearing in mind the number of workers envisaged to be placed on a panel, extensive planning of the stope layout, particularly concerning the length of panels and subsequent position of stope rock passes, is required prior to the ledging of a raise. It has been observed that in most instances panel lengths are much longer than a crew can handle per shift, resulting in improper support practices and low production efficiencies. If panel lengths are originally designed with the amount of workers to work on them in mind, panels could be properly supported, drilled and blasted almost daily, assuming all other parameters are favourable.

Another possible means of ensuring that support units are timeously and properly installed in the immediate face area is to assign each crew two panels that are adjacent to each other (provided there are enough faces to allow this). Figure 5.3.1 shows a mining sequence suggested for a crew mining two adjacent panels. Night shift cleans the panel and morning shift drills and blast the second panel supported by the previous shift. While the morning shift drill and blast a panel, the other panel (that has been cleaned by night shift) is supported by about six workers drawn from the morning shift crew. This practice enables the drilling and blasting activity to be done independently of support and hence ensuring both production and support efficiency.

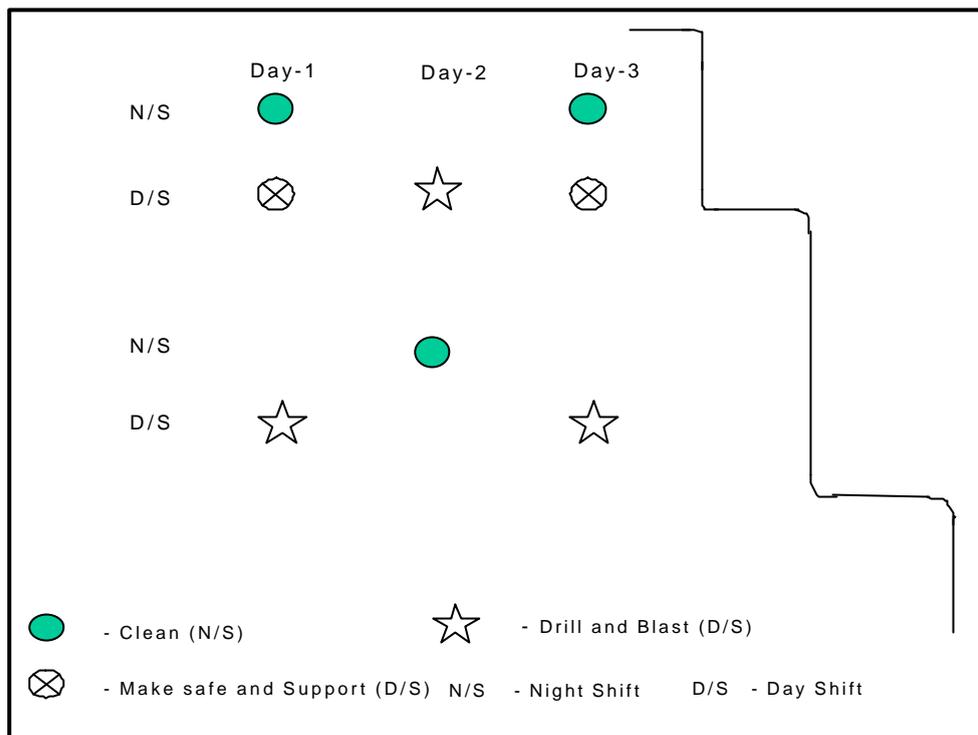


Figure 5.3.1 A proposed production cycle for a crew to improve on support installation practices.

5.3.1.3 Availability of support units

In general, mine policies, systems and procedures in respect of support delivery to the shaft were found to be adequate. The problem was found to be with getting the support units from the shaft to the working stope. The proper equipping of panels needs to be done to ensure uninterrupted transport of support to the face. Mono-winch routes should be separated from scraper and travelling paths. They should be regularly moved forward to minimise re-handling. Where possible, each panel must have its own independent support transport system to ensure a continuous supply of support units.

It is recommended that sufficient numbers of support units are always available in the stope within a reasonable distance from the face. Storage facilities, especially in backfilled stopes, should be incorporated in the initial stope design to enable the storage of removable support systems such as mechanical props or hydraulic props.

5.3.1.4 Stope width

Where the stoping width is dictated by the channel width of reef, little can be done to ensure a stoping width ideal for support practices. However, in situations where, due to poor mining practices, the stoping width has increased or decreased, thus constraining temporary support practices as enumerated in Section 4.2.1, the following are recommended:

- correct marking and drilling of shot holes,
- correct charging of holes,
- appropriate undercutting measures to be employed (e.g. rockbolting), and

- panels to be blasted frequently to prevent time dependent instability of surrounding rock mass, especially at great depth.

5.3.1.5 Dip of reef

In steeply dipping stopes, it is desirable to ensure good contact between the support unit and the strata. The use of elongates in steep stopes have in the past resulted in massive ride and collapse in shallow stopes. With the correct choice of in-stope pillar system the use of pre-stressed elongates will be beneficial. In deep level stopes, support installation angle of 90° to the dip of strata is of great importance. The stopes should be equipped with systems such as chains, gate stulls, etc., that will assist worker movement in the stope and minimise interference with face area support units by workers when moving up and down the stope.

5.3.1.6 Marking and drilling of shot holes

Rows of support offset such that the support units are aligned parallel to the drilling direction greatly reduces the problem of face area support units interfering with drilling activity.

5.3.2 Blasting

The use of blasting accessories and techniques that will minimise the blast out rate and damage to immediate face area support systems (without compromising blast efficiency), is worth investigating. The proper pre-stressing of support units, especially in very low closure conditions, is also desirable.

Shot holes should be drilled at the correct angle and charged-up as per the recommended procedure. During the underground visits, it was established that worker perception for over charging holes is to achieve the maximum advance, which in most cases results in support units either tilted, or blasted out, or blast-induced fracturing to the hangingwall.

5.3.3 Cleaning operation

The current practice on most mines, where cleaning crews are encouraged to install temporary support before any work commences, is seen to be a psychological solution rather than a technical one. This is because these support units will have to be installed on broken rock and against fractured hangingwall and are therefore prone to instability. Apart from the benefits of properly installed tendons (such as clamping of hangingwall partings and enough clearance for other activities in the immediate face area), tendons ensure, if drilled right up to the face, that immediate support is available for the cleaning and re-entry crews. Where the use of tendons is not feasible, the use of properly pre-stressed blast-on support systems should be encouraged. It is emphasized that the scraper size should be selected to match the spacing between support units, and not vice versa (i.e. support spacing selected to accommodate the scraper).

Rig holes should be drilled very close to the face, together with the face shot holes, and if possible equipped with the snatchblock by the drill and blast crew, to ensure minimum exposure of the cleaning crew to wide unsupported spans.

There should also be enough support supply, including the necessary accessories, available on panels for use by cleaning crews, should the need arise.

5.3.4 Other recommendations

It is suggested that refresher courses in rock engineering for management and other senior supervisors are frequently organised to maintain and focus management's attention on the importance of strata control. The same is applicable to the shift boss and the miner. The training and re-training of the team leader and his crew in hazard identification, basic strata control principles and correct support practices are essential.

Worker motivation, in respect of support practices, should be accorded the same status as production efficiency. More often than not human lives are lost or production has to be stopped for several shifts due to roof collapses associated with incorrect support practices, the reason being that there is a reward for face advance and not for good support practices.

The shaft ventilation network and stope layouts must allow the flow of sufficient quantity of air along the stope face at all times, as worker performance is enhanced in well ventilated working places. Excessive use of water and other practices that create humid conditions should be minimised to increase worker output in the stope, especially with support installation tasks.