6 Stability of unsupported spans in the production cycle

6.1 Introduction

Large unsupported spans are typical of certain cycle activities associated with stoping operations in the immediate face area. In this work, the production cycle is defined together with the activities associated with each. Based upon underground visits and discussions with relevant personnel, an attempt is made to quantify unsupported spans arising out of stoping practices for each cycle. A two-dimensional support design tool (SDA II, CSIR, 1999) was employed to determine the effect on stability of these increased unsupported spans during the identified unsupported periods for varying strata conditions.

6.2 Production cycle

Figure 6.2.1 shows the production cycle typical of the majority of underground gold and platinum mines in South Africa. As can be seen from the Figure 6.2.1, some of the activities are omitted in practical situations as the focus is on the drilling and blasting activities. In most cases the installation of support, drilling, charging-up and blasting activities are performed by a crew normally referred to as the morning shift. Similarly, the cleaning task is performed by the night-shift crew. Situations do arise when, for example, the morning shift does some cleaning and the night shift some support installation. In the discussion that follows, the work involved in the various activities is defined together with the situations arising when wide unsupported spans are created.

Figure 6.2.1 Typical production cycle.
6.2.1 Entry examination

The entry examination is the first activity to be supposedly done by the morning shift crew. The crew leader selects about three to four members of the crew to examine the panels and make them temporarily safe. At the time of entry these panels would be inadequately supported and unsupported spans between the face and the last line of support can be as high as 5 m. The procedure involves watering down and barring. The situation could be more hazardous when the practice involves the use of removable types of temporary support. The effect on stability of these increased spans is discussed in Section 6.3.

6.2.2 Temporary support installation

This activity is more often than not carried out simultaneously with the barring or the cleaning of the barred loose rock on the footwall. The top portion of the panel, which is the first place to be barred and cleaned, will automatically be the first place to be temporarily supported. The other portions of the panel, where cleaning and barring are still taking place, will involve workers moving under large unsupported spans. Once again, stopes using the removable types of temporary support are the most vulnerable. A high blast-out rate of blast-on type temporary support systems could also result in large unsupported spans. The effect on stability of such a configuration is determined in Section 6.3.

6.2.3 Drilling

The drilling operation is often done under temporary supported roof. The problem, however, often lies with other activities which take place in areas where drilling is not being done. In some instances, the support units are moved and placed as drilling progresses down the stope. The effect of this practice is the creation of large unsupported spans.

6.2.4 Permanent support installation

There are occasions when permanent support units are installed in place of temporary support. This could either be the installation of a pack right at the face instead of a mine pole due to perceived poor ground condition because the placement of the pole may be practically difficult. In such situations, the support unit may not exhibit the required stiffness. Also, such a practice slows down other activities such as drilling.

6.2.5 Charging-up and blasting operation

By the time the charging-up period starts, all temporary as well as permanent support units should have been installed. Extraction of the removable type of temporary support would have begun. Although there will be no one in the panel at the time of blasting, the extent of damage to the hangingwall as a result of the blast can be severe. This damage to the hangingwall could threaten the safety of the crew who enter the panel after the blast.


6.2.6 Cleaning period

This is the period considered to be the most susceptible to large unsupported spans. Some temporary support (i.e. the blast-on type) would have been blasted out by the blast the previous shift. The situation is even worse where removable temporary support units such as mechanical props are used. If the standard practice allows a maximum distance of permanent support from the face of 4,5 m, which is typical, an unsupported span of 4,5 m could be created. The night-shift crew enters such wide spans and performs activities such as the rigging of snatchblocks, splicing of rope, attaching the rope to scraper bucket, barring, lashing, etc.

6.3 Analysis of the effect of increased unsupported span on stability

6.3.1 Rockfall conditions – discontinuum

The effect on stability of increased unsupported spans within the immediate face area for varying fracture orientation and density was investigated using a two-dimensional support design tool (SDA II, CSIR, 1999) for typical shallow to intermediate stoping conditions. A beam thickness of 1,2 m, a stoping width of 1,2 m and a closure rate of 8 mm/m face advance were assumed. Further assumptions were that all discontinuities are non-cohesive and have an effective friction angle of 40°.

The support types employed are explained in the legend below:

SUPPORT TYPE LEGEND

- Likely region of instability
- Mechanical prop (Camlock)
- Mine Pole
- Pack (Composite or Solid mat pack)
- Elongate (Ebenhaeser Mk1 1,0 m Rockfall and Rockburst)
- Pre-stressable mechanical prop
- Hydraulic prop (Elbroc RB80)
As can be seen in Figure 6.3.1, instability of the hangingwall is likely to occur, irrespective of the support distance from face, due to the flat dipping face parallel fractures (55° away and 30° towards the face). In Figure 6.3.2, the stope was stable for varying unsupported spans. When the first row of temporary support was, however, 3.5 m from face, rock mass instabilities were likely. This support configuration, at which failure occurred, is typical of conditions under which the night shift works. A change in support type for removable support type, such as mechanical props, yielded similar results, except that, by its nature, the unsupported span could be as high as 4.0 m (see Figure 6.3.3). All configurations investigated as shown in Figures 6.3.1, 6.3.2, 6.3.3 and 6.3.4 gave stable conditions for fracture orientations of 55° dipping towards the face and 50° dipping away from the face (this is denoted as 55,50).

**Figure 6.3.1 Investigation of instability in the immediate face area for varying spans – shallow-dipping face parallel fractures.**
Figure 6.3.2 Investigation of instability in the immediate face area for varying spans – moderate dipping face parallel fractures (up to 55,50 degrees).

The support types were changed using mechanical props, Ebenhaeser mk1, and packs every 8 m. The results are shown in Figure 6.3.4 for varying support span from face. As can be seen, when the span from the support to the face exceeds 3,5 m (typical of an after-blast situation), the immediate face area failed.
Effect on stability of increased unsupported span, Fracture density=5/m, fracture orientation=55,40 degrees

Figure 6.3.4 Investigation into instability in the immediate face area for varying spans – moderate dipping face parallel fractures (up to 55,50).

6.3.2 Rockfall conditions – continuum analysis

A zone of influence of 1.5 m was assumed with no influence from the face. Typical shallow to intermediate hangingwall environments were used.

Figure 6.3.5 shows that for the support types and configuration used, the immediate face area is likely to fail in all cases. Although the extent of the failure was influenced by the degree of unsupported span, the fact that the support units in the first 6 m of the face are not stiff enough contributes to the extent of failure.
A stiffer support type (Ebenhaeser mk1, but not used in the immediate face area) was incorporated in the support layout as shown in Figure 6.3.5 and a reduction in the degree of instability resulted. However, the percentage instability was still a function of the degree of unsupported span with the post-blast situation being most unstable (typical of the night shift being the most vulnerable). The effect of not using stiffer temporary support types in the immediate face area is again highlighted in Figure 6.3.6 where non-yielding mechanical props, which are much stiffer, were used.

In Figure 6.3.7, a stiffer support unit (a prop pre-stressed to 10 tons) is used in the immediate face as a blast-on type support unit. It could be seen that the failed region was much reduced although the extent of failure was still a function of the degree of unsupported span. This means that the use of stiffer non-removable temporary support units should be encouraged for improved stability both before and after the blast. Control of their blast out rate is desirable as can be seen in Figure 6.3.7.
Figure 6.3.6 Investigation into instability in the immediate face area for varying spans - continuum analysis for shallow to intermediate conditions – effect of prestressing the immediate face area support units.

Figure 6.3.7 Investigation into instability in the immediate face area for varying spans - continuum analysis for shallow to intermediate conditions – effect of using stiffer, non-removal, blast resistant immediate face area support units.
The following conclusions are drawn from the analysis of the effect on stability of increased unsupported span for typical shallow to intermediate conditions under rockfall situations:

(i) Increasing support distance from the face results in an increase in the likelihood for failure.

(ii) The extent of the face area likely to fail is generally directly related to the type of installed support, the distance of the last line of support from the face and the spacing thereof.

(iii) The shift that normally enters the panel after the blast is most vulnerable. The situation is worse when removable temporary support units are used. The removable face support system protects personnel during drilling and charging-up activities; this support system is, however, not present during barring and cleaning of the stope face. These comments apply equally to the mine pole face support systems as many of the support units are dislodged by the blast.

(iv) The use of stiffer, non-removable blast-on temporary support units with adequate support resistance capabilities is recommended for use in shallow to intermediate depth environments, although it may not be able to completely eliminate the likelihood of failure in the stope face during all shift cycles.

6.3.3 Rockburst conditions – continuum analysis

The analysis used here assumes the rockmass to be one continuous unit with no discontinuities. A deep level environment was assumed, with a closure rate of 16 mm/m face advance and a stoping width of 1,2 m.

As can be seen from Figure 6.3.8, an unstable region 1 m from the face resulted after the blast. A further investigation into the situation, where every second hydraulic prop in the first row was blasted-out (may not be the case in a real situation), resulted in increased instability to 2,5 m from the face.

![Figure 6.3.8](image)

Figure 6.3.8 Investigation into instability in the immediate face area for varying unsupported spans - continuum. Elbroc RB 80 Hydraulic prop used as temporary support.
The effect on stability of increased unsupported span for the same support type and configuration, but for increased ejection thicknesses, is shown in Figures 6.3.9 and 6.3.10. As can be seen, an increase in the thickness of hangingwall layer ejected as a result of rockbursts influences the extent of failure in the stope face area. The general trend of increased instability, as a consequence of increasing support span from the stope face, holds.

**Figure 6.3.9** Investigation into instability in the immediate face area for varying unsupported spans - continuum. Elbroc RB 80 Hydraulic prop used as temporary support.

**Figure 6.3.10** Investigation into instability in the immediate face area for varying unsupported spans - continuum. Elbroc RB 80 Hydraulic prop used as temporary support.
In Figure 6.3.11, the effect of the use of an inappropriate support type in terms of yieldability is highlighted. This effect, coupled with increased support span, results in a wider area of instability in the face area as shown in Figure 6.3.11.

**Figure 6.3.11** Investigation into instability in the immediate face area for varying unsupported spans - continuum. Mechanical prop, Ebenhaeser MK1 1.0 m Rockburst and Pack.

The effect of the use of removable temporary support without enough stiffness and yieldability (a very common practice) under rockburst conditions is shown again in Figure 6.3.12. The support unit used was pre-loaded to 10 tons, which is typical in rockburst prone mines. Also shown is the importance of choosing the permanent support type with the appropriate load-deformation characteristics to ensure that, at worse, failure does not extend beyond it.
Effect on stability of increased unsupported span, Zone of support influence=1.5m, Ejection thickness=1.5m-2.2m

![Diagram showing stability of increased unsupported span](image)

**Figure 6.3.12** Investigation into instability in the immediate face area for varying unsupported spans - continuum. Mechanical prop, and an integration of Ebenhaeser MK1 1.0 m Rockburst and a Pack.

### 6.4 Conclusions

The following conclusions are drawn from the forgone discussion:

(i) Increasing support distance from the face results in an increase in the likelihood of hangingwall failure under both rockfall and rockburst conditions.

(ii) The extent of the face area likely to fail is a direct function of the type of installed support, the distance of the last line of support from the face and the spacing thereof.

(iii) The shift, which normally enters the panel after the blast, is most vulnerable. The situation is exacerbated when removable temporary support units are used. The removable face support system protects personnel during drilling and charging-up activities; this support system is, however, not present during barring and cleaning of the stope face. These comments apply equally to the mine pole face support systems as many of these support units are dislodged by the blast.

(v) The choice of support (both temporary and permanent) with the appropriate load deformation behaviour will greatly impact on the extent of failure in the stope face area.

(vi) The use of stiffer, non-removable blast-on temporary support units with adequate support resistance capabilities is recommended for use in shallow to intermediate environments, although it may not be able to completely eliminate the likelihood of failure in the stope face during all shifts. Under rockburst conditions, the ability for the support units to yield in a controlled manner without failing is suggested.