Stope Panel Rating System

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SYNOPSIS

This paper describes a continuous risk assessment system in use on a deep level gold mine. The risk assessment rates the location and configuration of stoping panels of the mine. This rating allows the objective setting of appropriate stope support standards in the panel rated. Each month the rating is revised resulting in a continuous modification of the support standard and conditions change. The paper describes the process of rating and the procedure followed after the rating has been done.

INTRODUCTION

The conditions in a deep level gold mine vary almost from panel to panel. To classify rock and strata conditions into normal and special categories do not properly represent the various conditions. The risk on a particular panel can change drastically in its lifetime, depending on the geological setting. Many different types of stope support are available with different specifications, characteristics and costs. In the past the design of stope support and special areas in particular has been rather subjective. The Mine Health and Safety Act require the manager to identify hazards employees may be exposed to, and to assess the risk.

Taken together, the above suggests that an objective system of evaluating risk in stopes is required. Based on this risk cost-effective support specifications can be set. This paper describes a system in use on Anglogold's Great Noligwa Mine that attempts to address the issues raised above.

CONCEPT OF RISK

The Mine Health and Safety Act defines risk as the likelihood that occupational injury or harm to a person will occur. The law requires the manager to identify, assess and record significant hazards and risks, to which people are exposed, and to record and make available these records to the employees. It goes on to require the design of safe systems of work to eliminate, control, minimise or to protect workers from this risk. In the design of the safe system, the manager must meet the requirements of reasonably practicable. Thus means that the manager will consider the severity and scope of the hazard, availability of means to eliminate the hazard and the cost and benefit of removing the hazard or risk.

Stoping is the major operation on a deep level gold mine, and an objective system of evaluating risk in stopes is required in terms of the law described above. Having established the hazard or risk a proper support system must be specified to eliminate / reduce the risk. The Panel Rating System (PRS) considers all of these factors.

PANEL RATING SYSTEM

When evaluating risk in a stope, two groups of factors are considered. These are controllable factors reflected by the Panel Index, and uncontrollable factors. The two groups of factors are combined to determine a Panel Rating, which is related to the level of risk. A support standard that reduces the level of risk is applicable to each Panel Rating (PR).

PANEL INDEX

The Panel Index (PI) reflects the controllable factors that can affect ground conditions and the level of risk within a panel. Essentially the PI is the hazard identification part of the PRS and attempts to compare or measure how well mining is being conducted against certain rock engineering principles.

Failure to adhere to these basic rock engineering principles results in poor ground conditions thereby increasing the risk of falls of ground. The Panel Index compares the real situation as reflected on the 1:200 stope sheets against what would be expected in an average panel.

There are five parameters in the Panel Index. In ranking these parameters a convention whereby the higher the value of the PI, the worse the conditions and the higher the associated risk. (This convention is used throughout the system.) It is possible to improve the Panel Index over time by adhering to basic rock engineering principles.

The parameters selected in this model are those which experience on the Vaal Reef has shown to be the most problematic in terms of contribution towards falls of ground in stopes. The exception to this is the presence or absence of a second access / egress, which was included in the system as it does influence the level of risk of a particular panel. The rating system used on the Vaal Reef at Great Noligwa Mine is included for information in Table 1.

Inter-panel Mining Sequence

The first parameter in the Panel Index considers the mining sequence between adjacent panels and between a panel and a major geological structure. Two basic rock-engineering principles are used as a guide in this parameter. First, leading against major geological structures and second, the avoidance of excessive leads and lags are considered.

Table 1

Panel Index Rating Criteria

Panel Index Parameter	Rating
Mining Sequence	
Lag against geological structure	5
Lag on both sides (between other panels)	4
Lag on one side	3
Leading other panels	2
In line	1
High stress concentrations due to face shape and lead/lag	
Poor face shape and lead/lag > 4.5m	5
Poor face shape and lead/lag < 4.5m	4
Good face shape and lead/lag > 4.5m	3
Good face shape and lead/lag < 4.5m	2
Good face shape and log lead/lag	1
Siding lag and/or gully lead	
Dip < 25°; siding lag > 4.5m or gully leading	3
Dip < 25°; siding lag > 4.5m	2
Dip < 25°; or in line	1
Approach and distance to geological structures	
Face parallel (or < 30°) to and < 10m from structure	6
Face oblique (or > 30°) to and < 10m structure	5
Face perpendicular to and < 10m from structure	4
Face parallel (or < 30°) to and > 10m from structure	3
Face oblique (> 30°) to and > 10m structure	2
Face perpendicular to and > 10m from structure	1
Second access / egress	
No	2
Yes	1

High Stress Concentrations due to Face Shape and Leads and Lags

High stress concentrations and associated adverse ground condition generally result from poor face shapes and excessive leads or lags. Faces should be kept as straight as possible and leads or lags reduced. An arbitrary cutoff of 4,5m has been used for leads / lags. This distance is historical and was taken from the mine standards.

Siding Lag and / or Gully Lead

Poor ground conditions are generally encountered in gullies as a result of an absent siding or when the gully is advanced ahead of the face. An arbitrary cut off of 4,5m has again been used but it is recommended that zero lags should exist. The level of risk in a panel is increased under these circumstances, as most workers in a stope will use the gully as an access to the face area. Historically a high percentage of accidents occur in gullies.

Approach and Distance from a Geological Structure

Geological structures generally represent planes of weakness. The manner in which such features are approached has an influence on ground conditions and hence affects the level of risk. The best-case scenario is to carry a face perpendicular to any plane of weakness.

Larger geological structures are often associated with joints and shear zones in close proximity to the discontinuity. This zone of weakness can be avoided by leaving a pillar against the geological structure. Since the level of risk increases closer to geological structures, special precautions should be taken.

Second Access / Egress

The presence or absence of a second access has no influence on the ground conditions in a panel. However, the level of risk is increased if no access is present. In many cases the presence of a second access is not shown on the 1:200 stope sheets. Under these circumstances the worst-case scenario is assumed and the panel is penalized.

RISK ASSESSMENT

An attempt is made to assign a level of relative risk to a number of uncontrollable factors. The risk assessment (RA) consists of two parts. First, the hazard is identified and second, some indication of the probability and severity of certain events occurring is assessed.

All of the parameters in the PR are regarded as uncontrollable. The parameters are not regarded as of equal importance and therefore carry different weights. The risk assessment part of the rating for the Vaal Reef is included in Table 2.

Geological Complexity

Geological Complexity is a function of the number of structures present and the type of structures. Geological discontinuities represent planes of weakness. Hence, the more disturbed the area is the higher the probability of falls of ground. An arbitrary cutoff of three geological structures has been used. This is based on what is generally experienced in the majority of panels on the Vaal Reef.

A distinction has been made between major and minor structures. A major geological structure is defined as structure, which intersects two, or more raise lines or has a throw of greater than three meters. Minor geological structures would be off-splits from major structures with a throw of less than three meters and which do not intersect two raise lines. Factors such as approach and distance to geological structures are considered in the PI. The possibility of large-scale wedge failure is catered for under Geological Complexity.

Mining Span (closure)

Mining span has been included into the system to cater for a specific problem, which is encountered in some areas on the Vaal Reef i.e. the problem of rapid closure (back break). Very low closure rates as a result of a small span are also considered hazardous as this affects the effectiveness of the support units installed e.g. Ledging.

Rock Burst Risk

The level of rock burst risk is the single most important parameter considered due to the fact that the consequences of a large seismic event are potentially far worse than those which may be experienced as a result of any one of the other parameters considered. Rock burst risk has the highest weighting factor in order to cater for the probability of rock burst associated damage and the increased potential for falls of ground during a seismic event.

Table 2
Panel Rating

Risk / Hazard Analysis Criterion List		Rating
1. Geological Complexity		
Very complex	(>3 minor structures at intersection of major structures)	5
Complex	(wedges, low angle structure sills, cross bedding, intersection of major structure)	4
Mod. Complex	(<minor structures)	3
Minor variations	(one small fault or dyke)	2
Simple	(no structure)	1
2. Mining Span (Closure rate)		
Small span	<30m or possibility of back break - wedge failure	5
Medium span	(30m - 60m)	3
Large span	(>60m))	1
3. Rock burst hazard / risk		
Very high	(remnant < 60m from seismically active structure)	5
High	(mining < 60m from a seismically active structure)	4
Medium	(mining 60 - 90m from a seismically active structure)	3
Low	(mining near a major structure with no history or 90m from seismically active structure)	2
Very low	(mining in open ground)	1
4. Face stress Regime		
Very high	(< 20m to holing, mining in a remnant)	5
High	(< 30m to holing)	4
Medium	(< 40m to holing or > 2 500m below surface)	3
Low	(open ground, 1 800 - 2 500m below surface)	2
Very low	(open ground, < 1 800 below surface)	1
5. Panel Index		
Very poor	(> 1.53)	5
Poor	(1.25 - 1.52)	4
Average	(0.97 - 1.24)	3
Good	(0.69 - 0.96)	2
Very good	(0.41 - 0.68)	1

In view of the potential losses, which may be experienced as a result of seismicity stringent precautions need to be taken in terms of support and mining sequence. These precautions include the upgrading of support resistance, bracket pillars and the optimization of mining sequence. Initially the determination of seismic / rock burst risk in an area was based solely on a perception of the seismic history of that area. The rock burst risk is allocated as follows: First seismically active structures are identified by means of the seismic history, and second, taking into account the position of a panel with respect to a presumed seismically active structure.

A number of conditions have been defined which are linked to distance away from seismically active or rock burst prone geological structures. A shortcoming of this approach is the necessity to identify seismically active geological structure, which is extremely difficult in a geologically complex scattered mining environment. The best available option is to relate the actual site response, i.e. recorded rock burst damage. Although this is reactive, it remains the only factual parameter.

Face Stress Regime

The face stress regime is a function of the distance to mined out areas, extent of mining and depth below the surface. All three of these factors have been included in the descriptions of Face Stress Regime.

Ultimately it is envisaged that numerical modelling will provide the input for this parameter. However, it is essential that the same variables and constants be used when modelling to ensure consistency. These relative values could be calibrated against actual stress damage and affects.

PANEL RATING

Combining the factors in the PI and the RA give an indication of the risk of the panel. First the controllable factors are rated and equation ˇ is used to determine the PI. The base figure of 12 is the value obtained rating an average pane. The maximum PI which can be calculated is 1,75 and the lowest is 0,41.

$$PI = (\Sigma \text{ Ratings of 1 to 5}) / 12 \quad \sim \quad ˇ$$

Next, the uncontrollable factors are rated. All the factors, including the PI are then weighted as follows:

Panel Index (PI)	=	x^2
Geological Complexity (GC)	=	x^2
Mining Span (MS)	=	x
Rock Burst Risk (R)	=	x^n
Face Stress Regime (FSR)	=	x

The following equation is used to calculate the Panel Rating (PR):

$$PR = (GC)^2 + (MS) + (R)^n + (FSR) + (PI)^2 \sim \quad ,$$

Where n = 2 if the rating is 1 to 3 and
n = 3 if the rating is 4 or 5

The highest weighting has been awarded to rock burst risk (R) as the potential consequences are the most severe. Geological Complexity (GC) and Panel Indices (PI) have been allocated the second highest weighting as these two parameters are generally responsible for the majority of falls of ground. Mining Span (MS) and Face Stress Regimes (FSR) have been allocated the lowest weighting as generally their contribution is somewhat less with respect to the level of risk in a panel.

The value calculated using equation[2] ,is meaningless at this stage. A relative scale is necessary to put this value in context. This is the same principle used in rock mass classification systems internationally. This scale is in effect the ranges for which the PR is defined. The scale use is as shown in Table 3.

Table 3

RISK	VALUES
PR 1 -2	0 to 50
PR 3	51 to 67
PR 4	68 to 93
PR 5	94 to 185

Any combination of parameters with a high rating will result in higher probability of an undesired event occurring. This cumulative effect results in a higher level of risk.

ACTION LEVELS

Certain actions are required to cater for the level of risk associated with the different Panel Rating classes. These Action Levels are based on the support strategies and standards used on different shafts. The Action Levels specify the type and density of support to be installed and certain other actions which may have to be implemented. Adherence to the Action Levels is a pro-active attempt to eliminate / reduce the level of risk in a particular panel.

The five Action Levels cater for the following conditions:

- Action Level 1 (PR = 1) Standard ledging
- Action Level 2 (PR = 2) Standard stoping
- Action Level 3 (PR = 3) Difficult stoping 1 ledging
- Action Level 4 (PR = 4) Stoping or ledging in good conditions but with a high rock burst risk
- Action Level 5 (PR = 5) Stoping or ledging in poor conditions

with a high rock burst risk

Generally the support criterion requirements for rock falls and rock bursts on the Vaal Reef are a support resistance of 28kN/m^2 and energy absorption of 21 kJ/m^2 respectively. These requirements have been determined from average falls of ground thickness, ejection thickness and peak particle velocities recorded in the Great Noligwa area.

SUPPORT DESIGN

The Panel Rating does not include support type in the calculation. Support is the means by which the risk is eliminated in the stope panel. For this reason the Mine has developed a range of support standards that can be used in stopes depending on the Action Level. These support standards are based on the calculation of the support resistance and energy absorption characteristics of different support media and layout. Using different support media and spacing a suite of stoping standards have been developed to eliminate the risk in a cost effective way. Basically, the support spacing is decreased and the support resistance and energy absorption is increased as the Panel Rating increases.

USE OF THE SYSTEM

On Great Noligwa Mine the Panel Rating is used in the following way:

- Once a month every working panel is evaluated using the Panel Rating System. This is done prior to the monthly planning sessions on 1:200 plans and the input of production and service staff.

- This evaluation is processed using a spreadsheet, and a Panel Rating is allocated. The Rating is recorded on the stope sheet.

- At the monthly planning session the Mine Overseer allocates an appropriate support standard to the stope. This determines the standard for the next month.

- During the planning session the reasons for the rating are investigated, and if the rating can be lowered by improving the controllable factors, instructions are issued for action during the month.

- The Rock Engineering personnel record and summarised the Panel Ratings. This information is used by various people to guide action during the coming month.

OUTPUT

Use of the system has resulted in the lowest Lost Time and Reportable Rates in the past five years, and the achievement of one million fatality free shifts - twice - by Great Noligwa. The system is under constant review and revision and it is hoped to train all stoping employees in the use of the system. It is believed that this will further improve the safety statistics.

CONCLUSION

The system described above goes a long way towards the elimination of risk in a stope panel using objective criteria. The risk assessment requirements of the Mine Health and Safety Act are met on an ongoing basis. Falls of Ground, which remains the cause of most underground accidents are addressed in a cost effective manner. Although the system is based on complex input and calculations, the outputs of these calculations are translated into meaningful actions by production personnel. Ultimately, the system has had a positive effect by reducing accidents on Great Noligwa Mine.

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