2012

A risk rating system for Anglo American's open cut coal mines in Australia

John Hoelle
Open Cut Geotechnical Engineering Group

Ismet Canbulat
Undergrounds

Publication Details

J. Hoelle and I. Canbulat, A risk rating system for Anglo American's open cut coal mines in Australia, 12th Coal Operators' Conference, University of Wollongong & The Australasian Institute of Mining and Metallurgy, 2012, 371-377.

A RISK RATING SYSTEM FOR ANGLO AMERICAN'S OPEN CUT COAL MINES IN AUSTRALIA

John Hoelle[1] and Ismet Canbulat[2]

ABSTRACT: There are a number of risk rating systems used at the Anglo American Metallurgical Coal's (AAMC) open cut coal mines in Australia. These systems are mainly mine site specific, geological based and the calculated risks are not comparable. Therefore, a uniform risk rating system, called OpenRisk is currently being evaluated and implemented for an unbiased, standard and quantifiable assessment of the risk form highwall and lowwall failures. This system is a semi-quantitative risk rating systems and takes into account the relative differences in the importance of hazards as experienced at each mine site as a result of different combinations of geotechnical factors and mining conditions. The system is based on critical geotechnical and other parameters that have been identified by site mining engineers, geologists and geotechnical engineers.

The primary advantage of this risk rating system is that all open cut mines in the AAMC operations use a near identical system, which enables the user to compare the risk with other mines. The system can be adjusted to meet local mine specific requirements.

The implementation of this system (a computer program that automatically calculates the risk) has been made as practical and as easy to use as possible. This program can be used by personnel from other mining disciplines not directly related to geotechnical engineering.

INTRODUCTION

Anglo American Metallurgical Coal operates five open cut operations located in Central Queensland and New South Wales (NSW). There is an increasing emphasis on safety and reliability at these operations. In addition, the Anglo American vision is to achieve "Zero Harm" through the effective management of safety at all businesses units and operations. In order to accomplish this vision, AAMC has implemented pro-active ground control management systems for a safe and effective production of open cut and underground reserves.

AAMC's pro-active ground control management involves an understanding of the impacts of the geotechnical environment on likely ground behaviour and consists of various elements (Canbulat, 2010; Hoelle, 2010). The safety record of these mines has been remarkable over the years. However, there have been a few recent highwall failures, which caused loss of production and could have resulted in injury to personnel. In order to prevent these unexpected failures, AAMC has initiated a project to evaluate and implement a risk rating system, called OpenRisk, that was developed by Canbulat *et al.* (2004) for Anglo Coal South Africa. The input parameters and the controls used in the program have been modified to local conditions in order to ensure that the results are representative of the environment the open cuts operate in Australia. The ultimate aim of this implementation is to minimise the risk to personnel and machinery by identifying the risks and by recommending a set of generic controls. A summary of risk rating system and the modifications implemented in Australia is presented.

APPROACH IN RISK RATING SYSTEM

OpenRisk has two distinct components, namely, controllable parameters and uncontrollable parameters. An advantage of this is that the ground conditions (uncontrollable parameters) and the responses to those conditions (controllable parameters) can be rated separately. There are compelling reasons for these to be rated separately. For example, perfect ground conditions can be turned into a high-risk environment by applying inappropriate mining practice, or very hazardous ground conditions can be turned into low risk environment by applying good mining practice. Such separation in the ratings ensures that:

[1] *Anglo American Metallurgical Coal, Manager Open Cut Geotechnical Engineering Group, john.hoelle@angloamerican.com, Tel: 0437534079*
[2] *Principal Geotechnical Engineer, Undergrounds*

- uncontrollable parameters are the true reflection of ground conditions present and cannot be changed;
- controllable parameters are the true reflection of the responses to those conditions and can be changed to reduce the overall risk.

The two ratings are, however, combined to produce an overall risk. The influence of changing a controllable factor on overall risk can be assessed using this methodology, thus evaluating the efficacy of modifications implemented.

An important consideration in OpenRisk is that uncontrollable parameters represent the magnitude of the inherent risks and is therefore called the Geotechnical Risk Rating. The controllable parameters represent the risk control factors applied in the open cut and are therefore called the Performance Rating. The combination of these two rating values represents the overall risk in the panel and is termed the Overall Risk Rating, Figure 1.

The parameters that form the basis of the risk rating system are drawn from systems previously used in Anglo American and hence they are based on local experience and knowledge. These parameters have been modified for the AAMC open cut operations.

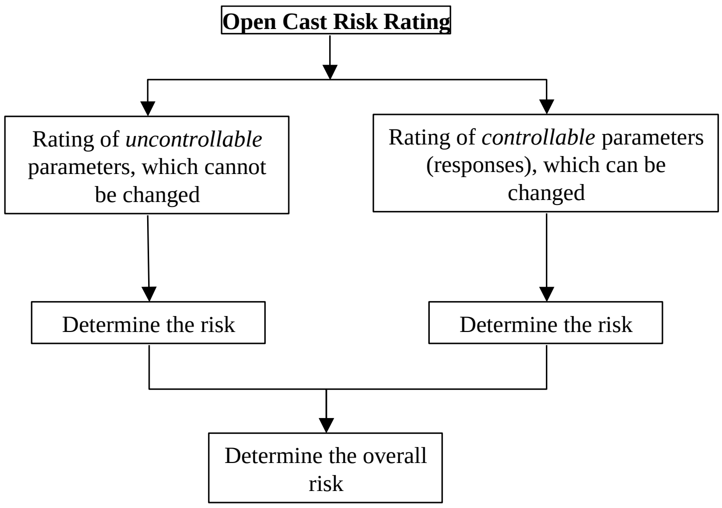

Figure 1 - Flowchart used in the development of the risk rating system

ADVANTAGES OF THIS DUAL-RATING SYSTEM

The advantages of this dual-rating system can be summarised as follows:

- easy to apply;
- does not require extensive training;
- the system provides an unbiased, standard quantified assessment of the risk from falls of ground, as the human factor is eliminated from the rating system;
- the likelihood of failure and stability can be assessed;
- consequences/severity of failure can be assessed;
- the risk or change in risk can be monitored over a period of time or face advance;
- controls/responses can be determined to reduce the risk;
- the performance of a crew can be determined over a period of time;
- the likelihood of failure can be assessed by implementation of controls; and
- if required, the ratings can be plotted on mine plans in real time.

PARAMETERS USED IN THE RISK RATING SYSTEM

OpenRisk methodology is common to all mines. It nevertheless allows for differences in the parameters rated and their weightings, according to mine specific experience and requirements. For example, while the effect of water may be a significant factor on the stability of highwalls in a certain mine, because of dry ground conditions, its effect on overall rating may be insignificant in another mine. Therefore, the weightings of each parameter are determined by the experienced mining personnel and geotechnical engineers from the various mines. The probability factor for each parameter is however kept constant.

Geotechnical risk rating parameters

In OpenRisk the geotechnical risk rating parameters are divided into four distinct categories, namely, geology, water, spontaneous combustion and dragline. The adjusted parameters and the probability factors used in the risk rating are presented in Table 1. This table shows that a total of 18 parameters are used in the geotechnical risk rating. Although all parameters are common to the systems used on all mines, manipulation of some of the parameters may however, be different for different mines.

Table 1 - Parameters used in the geotechnical risk rating system

	1) GEOLOGY		**1.10**	**Highwall condition**	
1.1	**Depth of weathering**			Stable	1
	0 - 5 m	1		Loose/rock/blocks	5
	5 - 10 m	5		Wedges/overhangs	10
	10 - 20 m	10		Zone of weakness	20
	> 20 m	20		**2) WATER**	
1.2	**Discontinuities**		**2.1**	**Water coming out of face bedding or structure**	
	None	1		NO	1
	1 (simple)	10		YES	10
	2 (complex)	10	**2.2**	**Is there water accumulation at toe of slope**	
	≥3 (complex)	20		NO	1
1.3	**Direction of discontinuities**			YES	10
	Not applicable	1	**2.3**	**Is there water on top of highwall/benches within 30m of crest**	
	Same direction (<30 deg.)	10		NO	1
	Different direction (>30 deg.)	20		YES	10
1.4	**Dipping structure / bedding**		**2.4**	**Rain**	
	Flat/dipping into the face	1		No rain in past 5 days	1
	Dipping into the cut	20		Rained in the past 5 days	5
1.5	**Clay material in bedding**			Has been raining for the past 5 days	10
	NO	1	**2.5**	**Head of water**	
	YES	10		No water	1
1.6	**Length of structure**			Stable, no increase	5
	0 - 1 m	1		Increase in water head	10
	1 - 5 m	10		**3) SPONCOM**	
	> 5 m	20	**3.1**	**Is the toe of highwall burning**	
1.7	**Presence of floor rolls and dipping seam**			NO	1
	NO	1		YES	10
	YES	10	**3.2**	**Is the toe of lowwall/spoil or any layer burning**	
1.8	**Major dykes/faults/burnt coal**			NO	1
	NO	1		YES	10
	YES	10		**4) DRAGLINE**	
1.9	**Cracks on highwall/benches within 10 m of crest**		**4.1**	**Dragline bench built on**	
	NO	1		Not applicable (truck & shovel operation)	0
	YES	20		Unweathered material	1
				Weathered material	5
				Weathered material and water	10

Discussions with geotechnical engineers and mining personnel revealed that certain mines require certain parameters in their rating system, while other mines do not require those parameters. For this reason, a "not applicable" option is also introduced in OpenRisk. In such cases, the parameter is taken out of the calculations

PERFORMANCE RISK RATING PARAMETERS

Performance parameters are divided into three distinct categories, namely, geometry, mining and blasting. The parameters used in the risk rating are presented in Table 2. A total of 17 parameters are used in the performance risk rating. Similar to geotechnical risk rating, a "not applicable" option is also introduced in the performance rating for three parameters.

Table 2 - Parameters used in the performance risk rating system

	1) GEOMETRY		**1.8**	**Noses present**	
1.1	**Batter back soft/weathered material**			NO	1
	Not Applicable	1		YES	20
	Yes / minimum 50 deg.	10	**1.9**	**Loose blocks at crest**	
	No / more than 50 deg.	20		NO	1
1.2	**Height of highwall**			YES	20
	0 - 35 m	1		**2) MINING**	
	35 - 50 m	5	**2.1**	**Undercutting spoils**	
	50 - 70 m	10		NO	1
	> 70 m	20		YES	20
1.3	**Angle of highwall**		**2.2**	**Undercutting highwall**	
	< 65 deg.	1		NO	1
	65 - 75 deg.	5		YES	20
	> 75 deg.	10	**2.3**	**Spoils in water**	
1.4	**Top bench width**			NO	1
	> 10 m	1		YES	10
	0 - 10 m	5	**2.4**	**Spoiling of weathered material at toe of spoils**	
	No bench	10		NO	1
1.5	**Spoils on the highwall**			YES	10
	Not applicable	0		**3) BLASTING**	
	< 15 m high/>10 m from crest	1	**3.1**	**Blasting method of highwall**	
	<15 m high/<10 m from crest	3		Pre-split	1
	>15 m high/>10 m from crest	5		No pre-split	10
	>15 m high/<10 m from crest	10	**3.2**	**Highwall condition due to blasting**	
1.6	**Height of spoils on lowwall**			Straight H/W no loose material	1
	Not applicable	0		Straight highwall, some loose material	5
	0 - 40 m	1		Frozen coal, overhangs, loose material	10
	40 - 95 m	5	**3.3**	**Pre-split barrels**	
	> 95 m	10		Not applicable	0
1.7	**Cut width (deviation from standard)**			Visible	1
	Standard within 5 m	1		Not visible	10
	Not standard (> 5 m deviation)	10	**3.4**	**Blast holes**	
				Visible	1
				Not Visible	10

WEIGHTINGS OF PARAMETERS

As is known that different parameters do not have the same effect on the overall panel rating system. The presence of one parameter may have a significant effect on the risk, while another parameter can have only a minor effect. It is therefore necessary to determine the weightings for each parameter in the rating system to ensure safe workings; each parameter is rated against the potential severity of the consequence. The weights of each parameter used in the geotechnical and performance ratings are presented in Table 3 and Table 4, respectively. In these Tables, "1" represents the lower severity, while "20" represents the highest severity.

CONTROLS

Introduction of controls, which are the actions to be taken for a given condition or risk level, can be implemented separately in the rating systems for different mines. These controls are automated to ensure that the risks can be negated almost immediately. However, the controls can also be introduced by the user in "Special Instruction" text boxes.

Preliminary lists of controls for different parameters in the geotechnical and performance ratings are shown in Table 5 and 6 respectively. It is however recommended that the controls should be reviewed and updated regularly to ensure the latest geotechnical engineering and local knowledge is available to the user.

CALCULATION OF LIKELIHOOD OF FAILURE AND SEVERITY

The following mathematical models are used in calculation of probability of failure (LoF) and severity (Sev) for both geotechnical and performance ratings:

$$LoF = \frac{\sum_{i=1}^{n} SPF_i}{\sum_{i=1}^{n} MPF_i} \tag{1}$$

$$Sev = \frac{\sum_{i=1}^{n} SPF_i \times W_i}{\sum_{i=1}^{n} MPF_i \times W_i} \tag{2}$$

Where:

SPF_i= Selected probability factor for each parameter;
MPF_i= Maximum of probability factor of each parameter;
W_i= Weighting of each parameter.

Table 3 - Weightings of parameters used in the geotechnical risk rating

	1) GEOLOGY	Weighting
1.1	Depth of weathering	5
1.2	Discontinuities	20
1.3	Direction of discontinuities	20
1.4	Dipping structure / bedding	20
1.5	Clay material in bedding	1
1.6	Length of structure	20
1.7	Presence of floor rolls and dipping seam	1
1.8	Major dykes/faults/burnt coal	10
1.9	Cracks on highwall/benches within 10 m of crest	20
1.10	Highwall condition	10
	2) WATER	
2.1	Water coming out of face bedding or structure	10
2.2	Is there water accumulation at toe of slope	1
2.3	Is there water on top of highwall/benches within 30m of crest	1
2.4	Rain	5
2.5	Head of water	1
	3) SPONCOM	
3.1	Is the toe of highwall burning	1
3.2	Is the toe of lowwall/spoil or any layer burning	1
	3) DRAGLINE	
4.1	Dragline bench built on	10

Table 4 - Weightings of parameters used in the performance rating

	1) GEOMETRY	Weighting
1.1	Batter back soft/weathered material	20
1.2	Height of highwall	10
1.3	Angle of highwall	10
1.4	Top bench width	10
1.5	Spoils on the highwall	1
1.6	Height of spoils on lowwall	5
1.7	Cut width (deviation from standard)	1
1.8	Noses present	10
1.9	Loose blocks at crest	10
	2) MINING	
2.1	Undercutting spoils	20
2.2	Undercutting highwall	20
2.3	Spoils in water	1
2.4	Spoiling of weathered material at toe of spoils	1
	3) BLASTING	
3.1	Blasting method of highwall	1
3.2	Highwall condition due to blasting	1
3.3	Pre-split barrels	1
3.4	Blast holes	10

Table 5 - Controls for the geotechnical rating parameters

1) GEOLOGY		Actions/Instructions
1.1	Depth of weathering	Batter, bench to hard, if it is soil batter to 45 deg., if it is weathered material batter to 60 deg. Conduct stability analysis; evaluate pre-strip
1.2	Discontinuities	Increase awareness of jointing. Conduct kinematic stability analysis;
1.3	Direction of discontinuities	Increase awareness of joint orientation. Conduct kinematic stability analysis;
1.4	Dipping structure / bedding	Increase awareness of dip of jointing. Conduct kinematic stability analysis;
1.5	Clay material in bedding	
1.6	Length of structure	
1.7	Presence of floor rolls and dipping seam	Determine the dip of the strata. Install monitoring.
1.8	Major dykes/faults/burnt coal	
1.9	Cracks on highwall/benches within 10 m of crest	Notify management and Geotechnical Engineering Department immediately. Install monitoring. Haul routes to be moved. Barricade the area. Ensure no equipment or men at the H/W.
1.10	Highwall condition	Increase the exclusion zone to 15 m
2) WATER		
2.1	Water coming out of face bedding or structure	Pump water and monitor the slope.
2.2	Is there water accumulation at toe of slope	Pump water and monitor the slope.
2.3	Is there water on top of highwall/benches within 30m of crest	Divert water and pump water out.
2.4	Rain	Monitor the slope. Pump standing water, if required. Slope may be affected up to 5 days after rain, therefore keep awareness high.
2.5	Head of water	
3) SPONCOM		
3.1	Is the toe of highwall burning	Sand dress the slope. Use water canons.
3.2	Is the toe of lowwall/spoil or any layer burning	Sand dress the slope. Use water canons.
3) DRAGLINE		
4.1	Dragline bench built on	

FINAL RISK RATING AND RISK CATEGORIES

The risk categories for geotechnical and performance ratings as well as overall rating are calculated by using the chart in Figure 2. The probability of failure and the severity are plotted in this figure and the risk areas for low, medium and high are determined with two linear lines. These lines are drawn based on a back analysis of failures and experienced gained from numerous different highwalls in South Africa and Australia. Although, it is not recommended to adjust these lines for different mines, they can be adjusted, using a back analysis of past failures.

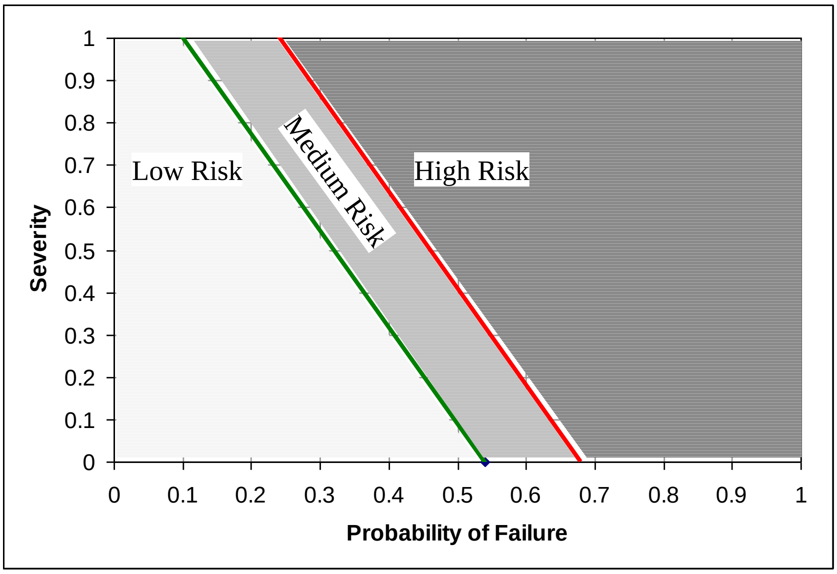

Figure 2 - Overall risk category chart

Table 6 - Controls for the performance rating parameters

1) GEOMETRY		Actions/Instructions
1.1	Batter back soft/weathered material	High hazard area, batter back, if possible. Mark & barricade off. No people, equipment or machinery under the H/W. Batter to 50-degrees
1.2	Height of highwall	Increase the exclusion zone to 15 m. Conduct stability analysis
1.3	Angle of highwall	Ensure dragline digs a straight H/W. Check the blasting practice. Review design parameters. Review mining procedure
1.4	Top bench width	All crests should have a minimum 10 m bench
1.5	Spoils on the highwall	All crests should have a minimum 10-metre bench; review design and mining procedure
1.6	Height of spoils on lowwall	Check dragline spoiling. Check cut width. Ensure spoil is not undercut. Extended bench may be required. Conduct stabilty analysis
1.7	Cut width (deviation from standard)	Spoiling room may be an issue. Extended bench may be required. Review 3D-Dig. Cut correct pit width. May require coal safety berm at least 20 m wide.
1.8	Noses present	High-risk area. Install monitoring. Initiate better scaling practices
1.9	Loose blocks at crest	Make/extend the exclusion zone at the toe of H/W to 15 m and ensure no people, equipment or machinery in the area. Monitor the area. Work under supervision. Scale if possible
2) MINING		
2.1	Undercutting spoils	Stop undercutting the spoils. Barricade the area. Install monitoring. Review mining procedure
2.2	Undercutting highwall	Stop undercutting the spoils. Barricade the area. Install monitoring. Review mining procedure
2.3	Spoils in water	Pump the water. Practice should be that spoil should never be dumped or shot into water.
2.4	Spoiling of weathered material at toe of spoils	Extended bench may be required. Double handle weathered material or mix with fresh O/B before spoiling. Review mining sequence to minimise placement of weak material at base of spoil
3) BLASTING		
3.1	Blasting method of highwall	Review blasting design & applicability to conduct pre-split on all highwalls and endwalls
3.2	Highwall condition due to blasting	Scale if possible. Review blast design and applicability.
3.3	Pre-split barrels	Review blast design and applicability.
3.4	Blast holes	

CONCLUSIONS

The risk rating system has been used on the Anglo American open cast coal operations in South Africa since June 2004 and is currently being trialled in Australia. Back analyses of the past instabilities indicated that while failing highwalls were rated and found to be high risk, stable highwalls were found to be low risk.

These initial results indicated that the risk system was consistent with reality and could be "trusted" to provide relative assessments of the open pits.

This risk rating system is primarily aimed at reducing the risk on the AAMC's open cut coal operations and ensuring the rock/ slope management strategy, as laid out in the Principal Hazard Management Plans and the Code of Practice. It is envisaged that OpenRisk will empower the employees on the operations to determine the risk and assists them in making quality decisions to determine the appropriate controls for these risks.

REFERENCES

Canbulat, I, 2004. Improved roadway roof support design for Anglo American Metallurgical Coal's underground operations. *Mining Technology: Transactions of the Institute of Materials, Minerals and Mining*, Section A. VOL 120 NO 1. pp 1-13.

Canbulat, I, Munsamy, L and Minney, D, 2004. A risk assessment tool for open cast mining In South Africa. Proceedings of 23rd *International Conference on Ground Control in Mining*. Morgantown, West Virginia. August.

Hoelle, J, 2010. Proactive Strata Control Management at Anglo American Metallurgical Coal Australian Open Cut Operations. Proceedings of 2nd *Ground Control Conference*, Sydney.