The Risk Management Process for Practising Geotechnical Engineers

Wouter Hartman

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Wouter Hartman
Level 19, 114 William st.
Melbourne
3000
+61 03 96708455
+61 03 96708311

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W. Hartman
Senior Geotechnical Engineer
AMC Consultants
Level 19, 114 William St.,
Melbourne
Victoria
3000
Australia
e-mail: whartman@amcconsultants.com.au

ABSTRACT

A structured Geotechnical Risk Management Process will assist you and your geotechnical team in defining and exploring pathways to minimise and even eliminate geotechnical risk situations. Experience in managing rock related risks shows that existing practices had various degrees of harm and a number of hazards are disregarded and sometimes not included in mining organisations global risk management strategy. The geotechnical risk management process will allow practising geotechnical engineers to identify key rock related risks to the operation and / or organisation. This process should be associated with previous experiences and whereby the human factor involved in each of the rock related activity process is defined. A mine wide baseline geotechnical risk assessment where all the rock related activities, which include a rock related incident and accident analysis, are processed analysed, will identify the geotechnical hazards and their expected severity associated with a specific re-occurring mining practice. The subsequent control underlining the assessment and analysis process are all part of the geotechnical risk management process.

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INTRODUCTION

Geotechnical Engineers, when subjected to a risk management[1] process[2], are in general concerned with rock related incidents[3], mechanisms of failure which include rockburst and gravity falls of ground and the severity or impact of any rock related incident on the mining operation. The Geotechnical Risk Management process should be a structured and formalised process and should be an integral part of the organisation's overall risk management strategy. It is a fully integrated system and does not stop at the geotechnical engineer's book shelve but rather a revolving and proactive process.

In December 2001 a MERIWA project report (i.e. Towards the elimination of Rockfall Fatalities in Australian Mines – No. 223) highlighted certain key learning points about the critical factors causing rockfall or rock related incidents. Of the 22 key learnings only six referred to risk issues, whilst the remaining 16 targeted specific rock related hazards. Those six key learnings are briefly highlighted below:

- "The collection and the analysis of rockfall data (even of variable quality) can be used to clearly define where most of the **risk**[4] lies, and evaluate the impact of changes in industry practices by plotting trends in time."
- "Of the 6 characteristics used to describe ground conditions in this study (shear/faulted ground, poor ground, blocky ground, good ground, groundwater, highly deformable ground), the **risk** of rockfall injuries is significantly higher in poor ground and blocky ground."
- "The **risk** of being injured by small rockfalls remains higher near the active face, however it is not confined to this area. Further away from the active face, there seems to be a recurrent risk of rockfalls resulting in at least 2 injuries per annum."
- "The Authors of the report believe that further improvement in surface support practices, within the framework of **risk management**, offers the best long-term

[1] Risk management is the complete process of risk assessment and risk control i.e. the result of a rational approach to risk analysis and evaluation, and the periodic monitoring of its effectiveness using the results of risk assessment as one input.

[2] A process is a series of actions, changes, or functions bringing about a result: eg *the process of digestion; the process of obtaining a driver's license.*

[3] An incident is an event or occurrence that attracts general attention or that is otherwise noteworthy in some way.

[4] Risk is the product (multiplication) of the probability of occurrence of a hazard by the cost of the undesirable consequences resulting from the occurrence of the hazard.

opportunity to further reduce the risk of rockfall injuries. The continuous emphasis on training, awareness and best rock mechanics practices is equally important."

- "The activities that present the highest **risk** are: barring down, rock bolting and charging. They account for over two thirds of the rockfall fatalities since 1993."

The above-mentioned report specifically targeted rock related incidents at mine sites. The conclusions reached by the authors of the report highlighted significant factors that cause rock related accidents[5]. I have found with numerous rock related incident and accident investigations, which ranges over an extended period and at various locations i.e. underground deep and shallow gold mines, underground shallow to intermediate platinum mining, shallow coal mining and open cut mines that their conclusions are similar to my own. However I would like to add a human factor, which is present at almost every incident. With this article I would like to highlight some of the human factors involved in rock related incidents and pathways we as engineers and managers can take to minimise geotechnical risk situations overall. Certainly the geotechnical hazard[6] identification[7] and risk assessment processes, if applied properly and is part of the company's risk management process, can offer huge economic benefits.

THE HUMAN FACTOR

The human factor I am referring to is the knowledge and experience contribution to all mining rock related practises. This includes works as early as the exploration drilling program and the follow on feasibility study; mine design process; the excavation and mining process; the review or reconciliation process and some training initiatives.

I have found from most incident investigations that the following factors are almost always present (ranking in no particular order):

- A general lack in understanding of how the rockmass behaves

[5] An accident is an event that is without apparent cause, or is unexpected. Generally an unfortunate event, possibly causing physical harm or damage, brought about unintentionally.
[6] Hazard is a condition with the potential to cause undesirable consequences. The term "Hazard" is often used to mean "source of a given magnitude".
[7] Hazard Identification – identifies the hazards and potential damages. Hazard identification answers the question, "What can go wrong?"

- The difficulty in identifying geological hazards
- Inexperience personnel
- Experienced personnel becoming complacent and
- Failure to communicate any change in rockmass behaviour

This lack in understanding of rockmass behaviour and difficulty in geological hazard identification includes a wide spectrum of mine personnel like the underground operators, mining engineers, planning engineers, mine managers, geologist, rock mechanics / geotechnical practitioners and some geotechnical consultants are not excluded from this spectrum.

Geotechnical input into mining practice according to a study (SIMRAC, 1998) is viewed as occurring in three phases:

- During strategic planning a broad approach is required for which a checklist method is appropriate to allow risks associated with alternative strategies to be compared.
- At a planing and design phase a detailed process interrogation method[8] is warranted to allow creation of procedures, operating practices and standards.
- During the operations phase, continuous review is needed to identify deviations from the optimum design and facilitate corrective action.

Checklists adapted to the appropriate level of monitoring are considered appropriate. However there are some limitations (SIMRAC, 1998) that everyone should be on the look out for when using a checklist to perform a baseline risk assessment:

- There are likely to be omissions. These should become fewer as the checklist is used and updated. One such example is the regular update of your mine’s stability graph and input parameters that reflect contributors to large falls of ground or stope collapses

[8] Process interrogation method is to examine by questioning formally or officially (narrative interviewing).

- The checklist is insensitive to situations that are subject to change and may, after some time, contain irrelevant questions
- Perhaps the greatest disadvantage with a check list is that it tends to put “blinkers” onto the user who becomes disinclined to look beyond checklist items for hazardous situations

An interesting study was conducted whereby “on the job”, off the job and an all industry performance” from 1912 through to 2000 exposure hours are compared (see Figure 1). Until the 1970’s, it was generally felt that the human component was reliable, and almost error free, particularly in relation to the high frequency of dysfunctions that occurred in other components (electrical, electronics, mechanical etc.).

FIG 1: DuPondt safety performance since 1912 (DuPondt, 2002).

Analyses of failures and accident demonstrate that human error may be regarded as either a generating or a permitting factor. Statistics related to human error are not easily interpreted due to the variability of the psychological and physical state of subjects at the moment of accidents. Stress compounds these parameters, and stress levels may differ substantially between daily routine activities, maintenance and repair functions or accident/crisis status. As a result, numerical values related to human errors are simply estimates that can vary greatly as a function of (Mine Info, 2004):

- Available time to react,
- Ergonomy of facility (design of human-machine interface)
- Experience and level of instruction, and,
- Stress

This leaves us with an open-ended question - “Will a Geotechnical Risk Management Process assist you and your geotechnical team to make sound geotechnical assessments and implement appropriate strategies to minimise geotechnical risk?” The following section will certainly expand the thinking process and highlighting the step-by-step process involved.

THE GEOTECHNICAL RISK MANAGEMENT PROCESS

The Geotechnical Risk Management Process (see Figure 2) starts with a complete geotechnical activity[9] statement (eg ***designing*** a shaft stability pillar).

FIG 2: Geotechnical Risk Management Process.

It continues into a comprehensive Geotechnical Risk Assessment Statement (eg ***All geotechnical factors are considered*** for an intact shaft pillar, which will influence the stability of an operating shaft). This is followed with a fairly detailed activity process map[10] (eg shaft pillar design activity process see Figure 3).

FIG 3: Example of geotechnical process map of shaft pillar design.

Each activity in the process is rendered significant to the overall goal of the operation and should be given a risk ranking to identify the high risk and where the focus in the process should be (see Table 1).

TABLE 1: Example of shaft pillar design activity process map ranking.

An estimation of the activity's risk to the operation is conducted using a combination of methods. The proper controls are carefully considered prior to final implementation. In completion of the Geotechnical Risk Management Process success and failures are assessed and channelled appropriately. The Geotechnical Risk Management Process should be used as a guideline when assessing any rock related activity or process (including geotechnical designs).
One of the underlying successes of the Risk Management Process is the identification of rock related hazards or activities. The methodology or process, which relates to some auditing factors, listed below, should be kept in mind:

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[9] An activity is a specified pursuit in which a person partakes.
[10] Process Map is a hierarchical method for displaying processes that illustrates how a product or transaction is processed. It is a visual representation of the work-flow either within a process - or an image of the whole operation. Process Mapping comprises a stream of activities that transforms a well-defined input or set of inputs into a pre-defined set of outputs.

- All geotechnical hazards that can create rock related incidents that could effect health and safety are identified
- The hazard identification methodology should be a structured process
- The methodology must be capable of prioritising geotechnical hazards to health and safety
- The results of the geotechnical hazard identification process are independent of team members involved

Some of the techniques, which will assist in identifying the hazards, are typical fault tree analysis, event tree, failure mode effect and critical analysis (FMECA) and HAZOP's[11]. The techniques however should not be used stand alone but rather in combination to identify possible root causes and outcomes. Previous studies have revealed that geotechnical hazard identification in itself is not a goal but rather a foundation from which to construct event-incident and cause-consequence-frequency relationships. It is essential that the process of geotechnical hazard identification and risk assessment follow a systematic format to ensure that all possible situations, activities and / or scenarios are identified and analysed. A process interrogation methodology is a preferred method but could be impractical for most operations due to time constraints and limited resources.

Practical steps that can be taken to ensure that geotechnical risks are minimised are given below:

- Management accepts accountability for the organisation's geotechnical risks
- It is almost a general consensus that each mining site must have a ground control management plan. Two of the topics that should be listed in the beginning of the document are i) all the rock related hazards (even installation of ground control counts as a hazard) and ii) a rockfall incident register[12] from which empirical ground support design methodology and reviews can be made.

[11] HAZOP is an abbreviated term for HAZard and OPerability study. It is a technique that identifies the potential hazards and operating issues with the design and construction of equipment and plant and involves the interaction of a multi-disciplinary team (Process flow technique).

[12] A rockfall incident register is record of all natural rockfalls in underground and surface mining. The record should include fall location, date and time, geometry (length, width and thickness), origin, rock type etc.

- Geotechnical audits or risks assessments take place by an independent reviewer
- New, inexperienced engineers and operators receive additional best practice training and offsite supervision (the loss of experienced engineers and operators compromises safety)
- Contractor's health, safety and environmental management systems are aligned with those of mining company – inclusive of adhering to ground control standards and procedures
- Discuss all rock related incident investigations and outcomes (i.e. standards or procedures) at management safety meetings and engineer / operator toolbox meetings

CONCLUSIONS

Experience in managing rock related risks showed that existing practices had some degree of harm and some hazards were found negligible and sometimes not included in an organisation's global risk management strategy. The geotechnical risk management process shows that it would allow the practising geotechnical engineer to identify key rock related risks to the operation and / or organisation. This process will be associated with previous experiences and identifying the human factor in each of the rock related activity of the process.

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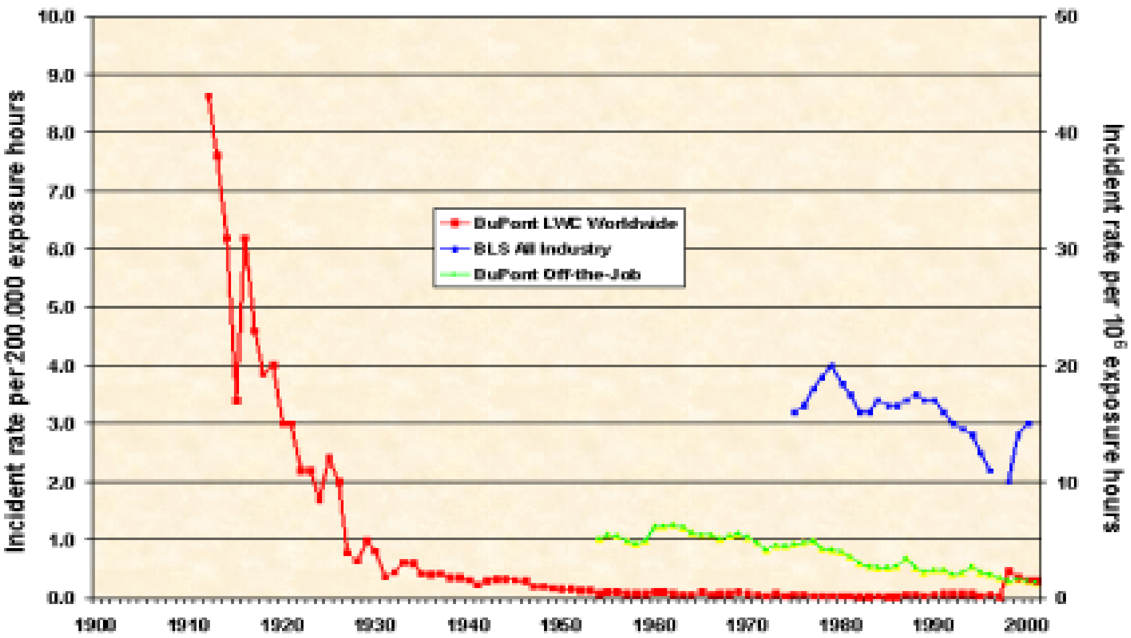

FIG 1: Dupont Safety Performance since 1912 (DuPont, 2002).

Geotechnical Risk Management Process

Define Rock Related Geotechnical Activity
State the motivation behind geotechnical
assessment (Incident, accident or review process)

Create Geotechnical Risk Assessment Statement
State objectives

Geotechnical Process Map
The entire process within which the risk is to be assessed
Description of actual happenings (sequence of events),
design process, support installation process etc.

Identify critical chain of Geotechnical Process
Use Matrix Analysis for Ranking, other methods
and database/experience on all rock related events

Estimate Risk associate with rock related activity
Combining possible severity with likely frequency from available information

Identify Proper Controls or Alternatives
Controls or alternatives for a clear reduction or
the illimination of risk to geotechnical / rock related activity
Responsibilities of key personnel clearly define

Implement the appropriate Geotechnical Risk Management Strategy
Based on perception of acceptable risk and
availability of resources

Monitorring

Success
Measured i.t.o.
safety statistics, monetary value etc.

Failure
Measured i.t.o.
safety statistics, monetary losses etc.

FIG 2: Geotechnical Risk Management Process.

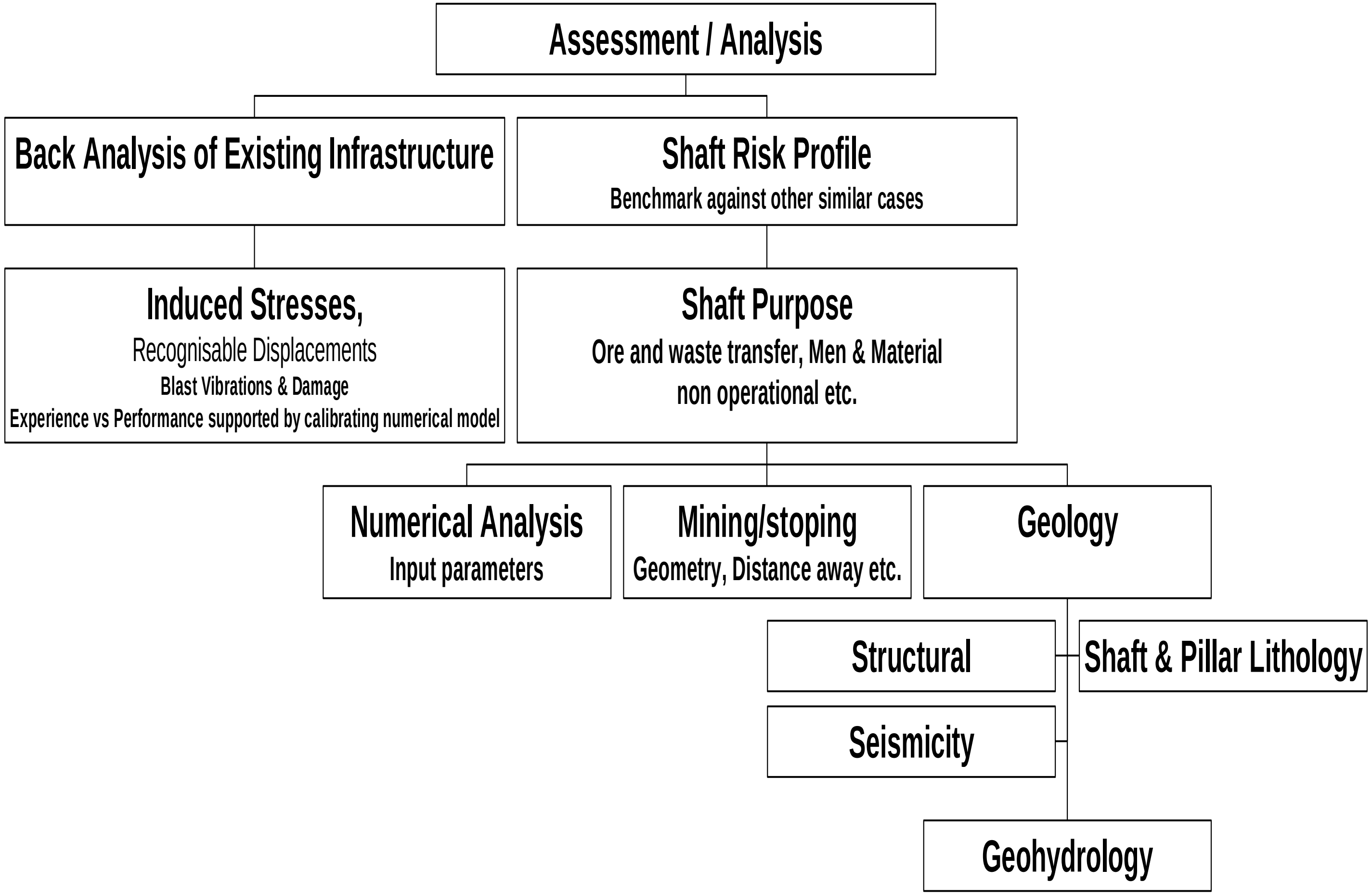

FIG 3: Example geotechnical process map of shaft pillar design.

	A	B	C	D	E	F	G	H	Total
A		0	0	1	1	0	0	1	3
B	1		1	1	1	1	1	1	7
C	1	0		0	1	1	0	1	4
D	0	0	1		1	1	1	1	5
E	0	0	0	0		0	0	0	0
F	1	0	0	0	1		1	1	4
G	1	0	1	0	1	0		1	4
H	0	0	0	0	1	0	0		1

A – Back Analysis of Existing Infrastructure
B – Shaft Risk Profile (shaft purpose)
C – Numerical Analysis (input parameters and model)
D – Mining/stoping (Geometry, distance away)
E – General Geology - Rock type
F – Structural Geology
G – Seismicity
H – Geohydrology

TABLE 1: Example of shaft pillar design activity process map ranking.