A New and Easy-to-Use Slope Radar Tool for Mine Production Crews

D. Noon GroundProbe, Brisbane, Australia
P. Bellett GroundProbe, Brisbane, Australia
L. Campbell GroundProbe, Brisbane, Australia

Abstract

Mine production and drill-and-blast crews may be exposed to unexpected movement of ground when working under pit slopes. Without specialist geotechnical advice and appropriate measurement systems, mine crews are faced with conducting risk assessments and relying on subsequent controls that may or may not be adequate to ensure their safety. Mine crews need an ‘early warning’ monitoring system to give them the confidence that they will have time to walk out of the danger zone if the pit slope begins to move.

Slope stability radar technology is used by mine geotechnical engineers to assess overall slope stability over an extended period, typically days or weeks, and to critically monitor slopes that are actively moving and may become unsafe. The complexity of slope stability radar allows for geotechnical engineers to assess movement types and movement rates across multiple work areas of a mine from long ranges, with alarm capability to a central location. However there are many mine work areas where production and drill-and-blast crews are not adequately covered or alarmed by slope stability radar systems. What is required is an easy-to-use, short-range, fast-scanning tool that can be operated directly by a work crew and can provide a local alarm with sufficient warning when a wall movement occurs within the work area.

The Work Area Monitor (WAM) concept has been developed specifically to be operated by a mine production crew. The system comprises a sensitive, fast-scanning radar coupled with a high-resolution camera, built into a mine-standard light vehicle. The system has been designed specifically for ease of use with the output being a local area alarm to warn workers of slope movement in their vicinity, as opposed to the broader pit monitoring and long-term deformation measurements of the known slope stability radar systems.

1 Introduction

Surface mining creates rock slopes that are often subjected to quite rapid stress changes during mining. In addition, these slopes can be influenced by significant external forces such as blast vibrations and changes in groundwater pressure. These conditions can lead to some degree of instability to develop in the pit slopes. The hazards associated with this instability of pit slopes can be extremely variable in character; ranging from small cobble sized rocks dislodging and falling from mine benches to complete collapse of entire pit walls. It is usually the position of mine geotechnical or geological staff to assess these hazards for mine operations.

Blast crews, in particular, are exposed to a number of slope related hazards including sudden or unexpected movement of ground in their immediate work area. Over the last few years there have been numerous near miss fatalities occurring from rocks, slabs and entire benches falling onto the blast area. Individuals and blasting equipment have been struck by rocks or have been in close proximity to the falls. Loading blastholes directly adjacent to pit slopes pose the largest risk.

Production crews are not equipped with the expert knowledge or tools to best understand whether a wall that they are planning to work under is and remains safe. In the absence of specialist geotechnical advice (which is based on visual observations and physical measurement over time), production crews rely on developed risk assessments which might not be ideal. Risk assessments look at factors such as proximity to the face in relation to the height of the face, face angle, face development (cut with machines, presplit, blasted), current face condition (presence of cracks, loose materials, etc) face geological condition, age of face, previous instability
and weather conditions over time to determine low to high risk ratings. This information relies on the experience and knowledge of the persons conducting the risk assessment and is only valid at the time it is performed.

Control measures to reduce the risk faced by production crews and other personnel and/or equipment working adjacent to pit slopes include; not entering the danger zone at all, scaling the slope, clearing catch benches, installing toe bunds, reducing the time and number of personnel involved, ensuring escape routes and having ‘spotters’ monitoring the wall. Although these control measures are valid, personnel working adjacent to pit slopes require an ‘early warning’ continuous monitor to give them the confidence that they will have time to walk out of the danger zone before a failure occurs.

2 Slope monitoring methods

The assessment of hazards due to unstable slopes can be done by visual observation of precursor signs such as fracturing or rilling of loose material. With these tell-tale signs, it is difficult to predict the progression of such signs to slope instability, and for brittle rock cases, the visible tell-tale signs may be too late. A more reliable indicator of instability involves the quantitative measurement of outward movement and acceleration of material as an instability mechanism develops. Development of a monitoring system, adopting acceptable slope deformation criteria coupled with warning systems and design of stabilization or risk reduction measures if appropriate has become a standard method of dealing with slope instability.

There are various monitoring systems that can measure the movement of the rock face (Little 2006). Geotechnical specialists can interpret the pattern and history of movement to improve prediction of the failure process, and to advise appropriate and timely stabilisation or safety management actions. Mines can use such information to more reliably assess risk and maintain records for due diligence purposes (Bye, Little and Mossop, 2005). In addition, monitoring systems can sound an alarm to warn workers when the movement or acceleration of the rock face exceeds a set threshold.

Current monitoring methods at some mines use extensometers and prisms to measure the face movement or dilation of cracks appearing on the crest or face of the rock slope. These methods monitor points or lines on the wall rather than the area of the wall face, which makes interpretation of failure mechanisms very difficult. In addition, these methods are time consuming to set up and relocate because they usually require the careful placement of sensors or reference reflectors on unstable or inaccessible ground.

Slope stability radar is the preferred technique for monitoring mine walls and general slopes (Noon and Harries, 2007). Slope stability radar systems monitor movement of open cut mine walls with sub-millimeter resolution over entire areas of walls (see Figure 1). This capability allows wall movements to be detected and displayed prior to a failure of the wall. The high level of movement precision and broad area coverage of the rock face can allow for a better understanding of the geomechanics of slope deformation, including magnitude of potential failures and additional warning time of impending instability (see Figure 2).

Slope stability radar systems have been deployed in many metalliferous and coal mines throughout the world. Over 150 Slope Stability Radar (SSR) systems are currently being used across 19 countries. Greater than 500 rock slope collapses and waste dump failures (from several to millions of tones) have been monitored to date, with ‘warning’ precursor movements recorded by the system. This technology has enabled a radical change in the management of risks in open cut mining.

Slope stability radar technology is used by mine geotechnical engineers to assess overall slope stability over an extended period, typically days or weeks, and to critically monitor slopes that are actively moving and may become unsafe. The complexity of slope stability radar allows for geotechnical engineers to assess movement types and movement rates across multiple work areas of a mine from long ranges, with alarm capability to a central location.
However there are specific work areas in a mine that are not adequately covered or alarmed by slope stability radar systems. What is required is a simple short-range, fast-scanning tool that can be operated directly by a work crew and can provide a local alarm with sufficient warning when a movement occurs within the work area.

3 Work area monitor

The Work Area Monitor (WAM) concept has been developed specifically to be operated by a mine production crew. The system comprises extremely sensitive face-scanning radar coupled with a high-resolution camera, built into a mine-standard light vehicle (Figure 3). The system has been designed specifically to be a simple and local area alarm to warn workers of slope movement in their vicinity as opposed to the broader pit monitoring and long-term deformation measurements of the known slope stability radars.
The monitor is a comparatively short range device that provides movement monitoring of slopes at a range of about 30 metres to about 250 metres. In operation, the light vehicle is orientated so that the radar and camera point at a section of slope or wall to be monitored. An image of the slope as seen by the camera is displayed on a touch screen in the light vehicle cabin. The operator selects the ‘look’ area on the touch screen using the camera image and the radar rapidly scans a grid of cells for movement (Figure 4). When movement in one or more cells is triggered, an audible and visible alarm (Figure 5) is sounded. The precise location of the wall movement is determined using the camera image (Figure 6) on the touch screen in the cabin. The light vehicle enables the blast crew to quickly and easily move the system as they progress along the blast pattern.
The amount of movement alert threshold is selected above the noise stack of the system. The output of the monitor is a binary alarm based on whether wall movement has been detected (‘1’) or not detected (‘0’). The monitor operates over a short time scale of minutes and hours, and alarms when there is movement in the local work rather than providing displacement measurements of the slope over days to weeks as is the case with conventional monitoring systems.
It has been found from many measurements of slope failure using slope stability radars, that initial movements of a few to many millimetres are always present as a precursor, even for rapid brittle failures (Harries, 2009). Thus, as a safety device, the monitor is very useful as a short term, short range safety device that detects movements of a few millimetres or more and provides a warning to workers in the immediate area.

4 Conclusions

Production crews are exposed to unexpected movement of ground when working adjacent to pit slopes. Without specialist geotechnical advice and appropriate measurement systems, production crews are faced with conducting risk assessments and relying on subsequent controls that may or may not be adequate to ensure their safety. Production crews need an ‘early warning’ monitoring system to give them the confidence that they will have time to walk out of the danger zone if the pit slope begins to move.

Slope stability radar technology has provided mine geotechnical engineers with an excellent tool to assess overall slope stability over extended periods. The Work Area Monitor now provides production crews with a tool that in less than 1 minute after deployment and every minute thereafter, can let them know if the slope they are working adjacent to has moved. This tool will provide confidence, help eliminate uncertainty, and is a major step forward in protecting production crews from rock falls.

5 References


