Health monitoring
How telematics and cloud computing are transforming the mine-maintenance landscape

Preconcentration
Industry experts explain the available options and how mines around the globe are benefiting

Slope monitoring
The latest technologies and trends
No longer a slippery slope

Slope monitoring in the surface-mining industry has become routine practice to support mining staff in the management of geotechnical risks. Albhe Goodbody finds out more

Slope monitoring forms an integral part of slope management in open-pit mines, and is important for two key reasons: the most obvious is the cost and safety challenges imposed by pit wall instability should a failure of significant volume occur. Advanced slope monitoring techniques also allow operations to mine to the steepest limit possible while meeting safety objectives, allowing for more ore to be recovered for less cost to the operation, and potentially resulting in lower stripping ratios and reducing operational costs.

Ultimately, not knowing about the stability of pit walls may result in slope failure. Such slope failures in large open-pit mines represent a major challenge for the safety of mine operators and mine assets. Mining operators may risk exposing their workers to potential injury, or even death, where land movement is severe.

James Howarth, product manager, mine measurement at Maptek, says: "The safety factor is absolutely critical – one doesn’t have to look far to find examples of major incidents at mine sites when no adequate slope monitoring system was in place."

In addition, a pit-wall collapse results in a halt to active mining. Such interruptions of operation are not only very challenging to plan for, but can result in a significant cost being incurred through equipment and personnel downtime. "Lost time equals a loss in product, which results in a loss in operational value and profits," explains Howarth. "Beyond this, the cost of removing material after a pit wall collapse, and the inability to plan for material that has been displaced, can lead to major cost blowouts in open-pit mines."

The resultant loss in infrastructure can also have huge consequences on industries that are dependent on the mining industry’s output.

Early detection of any movement in slopes, highwalls and benches is critical in mitigating the risk of pitwall failure and minimising disruption to normal operations and planning. Niccolò Coli, manager of the IDS GeoRadar mining business unit, says: "Small surface movements on a mine highwalls may be precursors of large failures that, if properly measured, can provide sufficient pre-warning to enable workers and machinery to be withdrawn to safety."

As a result, an effective real-time critical monitoring system is required to manage groundfall hazards with enough confidence to effectively support critical decision-making. It provides information that can detect potential unstable ground, as well as assess the performance of slope design. This involves identifying any slope instability and understanding appropriate failure mechanisms.

Thomas Gaiser, senior manager for international sales and mining specialist at Riegl, notes: "With the majority of mining activities taking place at ground level, up-to-date knowledge about the integrity of the pit walls is vital to meet requirements of operation safety standards. Keeping a 'digital eye' on slope changes and rockfall provides valuable input not only to plan precautionary measures, but also to document the effectiveness of such."

If failure mechanisms are understood and the slopes are properly monitored, the risk of slope movement and the subsequent consequences can be considerably reduced. This allows for optimal mining conditions that are safe for mine personnel as well as working equipment.

In order to achieve this, a mining company needs to find the most...
adequate monitoring solution that meets all the necessary requirements, which is often a challenge.

Dr Neil Slatcher, research and development manager at 3D Laser Mapping, tells Mining Magazine that the main objectives for a slope monitoring strategy are:

- Maintaining safe operational systems and procedures to protect personnel and equipment;
- To provide notice of potentially unstable ground so that mine plans can be modified to minimise the impact of slope displacement;
- To provide geotechnical information for analysing any slope instability failure mechanisms, including the design of an appropriate remedial action plan and conducting future slope designs;
- Assessing the performance of implemented slope design; and,
- Building up a history of information to determine different rock behaviours over a long period of time of monitoring.

Latest trends

Laser scanners are ideal for collecting baseline data and for visualising changes in surfaces. Howarth says: "In addition to the obvious benefit of being able to capture accurate survey data from a safe distance, laser scanning creates an immediate record of structures such as undercutts. When undercutts collapse along vertical joints, steep slopes can form."

There has been a tremendous increase in data-acquisition speed and accuracy in laser scanning in recent years. Gaishecker adds: "Additionally, the instruments have been coupled with additional sensors such as cameras or inclination readers for additional information to the pure geometry data. Just recently, the first systems with enhanced on-board processing and communication devices have been released, all contributing to the idea of connected sensors throughout the mining area."

In addition, automatic classification approaches using laser scanners are improving all the time. Slatcher says: "It is possible to automatically map and classify surface geometry in great detail, measure fractures and remove vegetation from laser scans, which can cause false alarms in monitoring datasets."

He adds: "Integration of photogrammetry and laser data is also enabling 3-D surface displacements and enabling 3-D surface displacements to be automatically measured in great detail, gathering data such as magnitude and displacement direction. This type of information is essential in determining the current state of a slope and identifying potential signs of slope failure."

Case studies

IDS GeoRadar has hundreds of systems installed worldwide that are used for safety-critical monitoring of slope hazards. "One of my best examples is a gold mine operated by a major mining company in the US," notes Coll. "They acquired the first IBIS monitoring radar in 2009, and ever since they have implemented IBIS radars as the primary safety-monitoring system for their operation."

"Recently, they have successfully managed a multiple-bench failure with IBIS-FM and IBIS-Rover systems. IBIS-FM is set to provide a long-range wide coverage of the entire work and picked the first onset of the movement that was developing right above a working area. Alarms went off in due time, allowing the geotechnical crew to trigger TARPS procedures and safely evacuate the area."

The IBIS-Rover has since been deployed as a tactical monitoring system focusing on the movement and surroundings to guarantee the safety continuation of works after the failure.

Coll says: "This is a perfect example of how a skilled team of geotechnical engineers can take advantage of the capabilities and flexibility of IBIS radars to manage risks and cover different monitoring needs."

Maptek’s Sentry system has proven to be a very important tool for monitoring rock movement at Kamantoo copper mine, operated by Hillgrove Resources in South Australia. Howarth explains: "The Sentry system was initially set up to collect data in the Nugent pit. The location, size, run out distance and time of occurrence of minor rockfalls were identified, providing precise data to be incorporated into the Hillgrove rockfall risk management programme."

Several rock movements were detected in the initial months of the system operating, including initial rock dilation, small rockfalls and a slump failure before a flexural topple event, in which columns of rock separated by discontinuities broke as they bent forward, and occurred. "A slope stability radar was used to successfully provide alarming capabilities, allowing operations to retreat from the area on the day before the final wall collapse," says Howarth. "A Maptek I-Site laser scanner was also used throughout the development of the toppling failure to monitor movements, starting from initial dilations through reverse scarps and to the final collapse. It was proven to be as reliable as the radar systems."

A second laser-based system was then set up in Kamantoo’s Emily Star pit. The scanner detected rock displacement movements on an area of the near vertical eastern wall, just to the south of a stability buttress. "Inspections indicated that block toppling might eventuate so alarms were set in the Sentry system at 2mm/hr (geotechnical alarm) and 3mm/hr (critical alarm)," states Howarth. "The two alarm levels were activated at 2pm and 6pm on the day before the failure eventually occurred, providing several hours’ notice for safe evacuation of personnel and equipment."

IDS GeoRadar’s IBIS-Rover is a mobile monitoring solution
**System providers**

Various technologies, such as radar, robotic total stations and laser scanning, are used to perform monitoring tasks.

*Mining Magazine* talked to several companies that provide monitoring systems for the surface mining industry about their latest solutions and where they’re focusing their research and development.

**3D LASER MAPPING**

3D Laser Mapping’s SiteMonitor system is based on a laser measurement component (laser scanner) for monitoring the rock face. “The principle behind the software is to establish a grid of measurement points and to re-measure the grid periodically to look for differences in the position of the grid nodes,” explains Slatcher. “This system was designed to provide simple-to-use, reliable solutions with the flexibility to function in a wide range of monitoring applications.”

SiteMonitor can be used to measure and monitor:
- The stability of slopes and structures;
- Changes in volumes;
- Deformation;
- Long-term trends of rock behaviour;
- Rockfalls; and,
- Changes in slope hydrology.

---

**“Laser scanners are ideal for collecting baseline data and for visualising changes in surfaces”**

---

Top to bottom: A point cloud showing the contours of an open cut mine; automated volume calculations using LiDAR.

---

**RIEGL® VZ-4000**

3D Terrestrial Laser Scanner

With the RIEGL VZ-4000 Laser Scanner and specifically designed software packages, RIEGL provides a perfect solution for the demanding fieldwork in open pit mining and topography.

- up to 4,000 m range
- eyesafe Laser Class 1
- accuracy 15 mm, precision 10 mm
- Laser Pulse Repetition Rate up to 300 kHz (222,000 meas./sec)
- multiple target capability
- multiple-time-around (MTA) processing
- full waveform export capability (optional)
- built-in camera, on-board inclination sensors, GPS receiver and compass integrated, external GNSS receiver (optional)
- stand-alone operation

Visit us at September 13-16 Jakarta, Indonesia booth A-3105

www.riegl.com
The success of safety critical monitoring solutions is fully dependent on getting important information to end-users as quickly as possible.

IDS GEORADAR
Interferometric radar technology, which is embedded in IDS GeoRadar's IBIS solutions, is one of the leading tools for slope monitoring in the surface mining industry. "The success of slope-monitoring radar is attributed to its ability to rapidly measure slope movements with sub-millimetre accuracy over large areas," states Coli. "As a result, IDS GeoRadar slope monitoring radar is effectively used for the provision of real-time alerts in the event of progressive movements that can potentially lead to mine slope failure."

IDS GeoRadar was the first company to introduce a slope-monitoring radar based on the synthetic-aperture radar (SAR) technology to the mining market – it had previously been successfully applied to landslide and dam monitoring.

"Since the first deployments in open-pit mines, the IDS GeoRadar technology has demonstrated its potential thanks to its superior capabilities and performance compared to dish-antenna radar," says Coli. "Today, the high number of installations worldwide in open-pit mines owned by major mining companies, and the hundreds of detected slope failures, clearly demonstrate the benefits introduced by SAR over conventional radar technology for critical slope monitoring."

IDS GeoRadar has constantly evolved the SAR technology to satisfy multiple needs in different mining scenarios. Today, the company offers a vast portfolio of SAR radar units able to adapt to all monitoring needs: mobile and semi-fixed solutions, flexibility for tactical deployment and long range for strategic coverage, as well as IBIS Guardian TrueVector, its most advanced and complete data processing software.

At the beginning of June, the company introduced its next-generation radar system based on the ArcSAR technology. IBIS-ArcSAR delivers excellent flexibility and performance to support geotechnical engineers in critical decision-making. Coli tells MM: "IBIS-ArcSAR is the first and only radar in the mining industry to provide up to 360° field of view from one single platform. The system leverages the widest and longest range (5,000m), and the shortest scan time (360° in 40 seconds; 180° in 20 seconds)."

In addition, the spatial resolution of 10 million pixels improves critical safety monitoring by covering the full scale of slope instabilities, from sub-bench to broad wall move-
The Riegl VZ-1000 terrestrial laser scanner at an open-pit coal mine in Indonesia

"There has been a tremendous increase in data-acquisition speed and accuracy in laser scanning in recent years."

Slopes movement, and the software allows operations to monitor and analyse movement over time.

"One of the biggest advantages is that Sentry provides data to support constant surface monitoring required by geotechnical teams, and mine management for managing risk, as well as adding value to the mine design and planning processes," points out Howarth. "Seamless data exchange with I-Site Studio software allows specialist geologists and engineers to conduct further analysis including geotechnical studies. The 3-D point cloud data can then be interrogated to provide information to update rockfall databases for reducing risk in the vicinity of high-wall toes."

This approach allows operations to use laser-scan data collected by Sentry to track rockfall movements in i-Site Studio, as well as calculate volumes and conduct geological mapping.

Sentry also supports operational and productivity objectives through safe, achievable and cost-effective slope monitoring in remote and rugged areas.

It monitors and maps the complete scene, producing a true digital terrain model for 3-D viewing. The laser scanner can be removed for other site survey tasks. Howarth says: "When the scanner is set up repeatedly over the same fixed location, Sentry maintains a continuous monitoring history for identifying and analysing trends. Monitoring frequency and notification thresholds are fully customisable, providing accurate, useful results."

PerfectDig is another Maptek laser-based measurement solution. It delivers an intuitive system for rapidly evaluating and supporting design conformance in the field. Operations using it can benefit from improved decision making and resource recovery. Howarth explains: "A major advantage is that PerfectDig exposes the same single source of information to engineers, surveyors, supervisors and management, or quickly comparing as-built with designs in the field, fostering real-time decision making. Streamlined workflow allows users to drive up to an area with the I-Site laser scanner mounted on a site vehicle, and click to scan. PerfectDig scenes are automatically generated and registered.

"Another click compares these scenes to designs with advanced tools for querying the captured scene. Cross-section, blockline and distance to design options easily measure and report volumes, depth and width of areas of misconformance. Reporting is fast and simple. Users simply specify data and region of interest to generated automated conformance reports for viewing on mobile devices and sharing via online platforms."

Maptek continually looks to add value by examining how data collection and analysis can extend across processes and beyond horizons. "Maptek combines feedback from the mining industry with best-practice software engineering to develop mining solutions ahead of the game," says Howarth. "Maptek recognises that connectivity holds the key to maximising productivity. We are integrating our software solutions on the Maptek Workbench and providing access to third-party applications that will allow customers to connect their systems and processes operation-wide. Attention to detail in data collection at every stage of mining, including attention to processes up and downstream from the collection stage, will lead to auditable systems and continuous improvement."

The Maptek Technology Roadmap outlines key steps in the company's technology development plan for the next five years. Howarth declares: "In the mine measurement arena customers can be confident that Maptek will embrace emerging technologies and platforms, and explore new ways to enhance the success of their business."

Riegl’s 3-D laser surveying systems are based on Waveform-LIDAR technology. This technology provides accurate, long-range distance measurements over several thousand metres at high speed, independent from daylight. Gaiseker says: "Thanks to the Waveform-LIDAR technology, the systems are capable of capturing multiple targets and therefore provide accurate range through readings of areas for instance covered by safety nets."