Swiss Re
Corporate Solutions

Risk Engineering Services

Geotechnical Failures

The potential for instability in the rock surrounding mine excavations is an ever-present threat to both the safety of men and equipment in the mine.

In order to counteract these threats, it is necessary to understand the causes of the instability and to design measures which will eliminate or minimise any problems.

Background

Unlike civil excavations, where the emphasis is placed on reliability and the long-term performance of the design and cost/benefit is less of an issue, mining excavations are normally constructed to lower levels of stability which recognises the shorter operating life spans involved and the high level of monitoring (both in terms of accuracy and frequency) that is typically available at a mine. Although this approach is fully recognised both by the mining industry and by the regulatory authorities, risk tolerance may vary between companies and between mining jurisdictions.

Understanding the risk

Types of instability can include:

- Falls of ground
- Rock burst/seismic events
- Rock Slope failure
- Rock fall

Uncontrolled instability, in effect failure of an excavation, can have many ramifications including:

- Safety/social factors
  - loss of life or injury;
  - loss of worker income;
  - loss of worker confidence;
  - loss of corporate credibility, both externally and
  - with shareholders.
- Economic factors
  - disruption of operations;
  - loss of ore;
  - loss of equipment;
  - increased stripping;
  - cost of cleanup;
  - loss of markets.
- Environmental/regulatory factors
  - environmental impacts;
  - increased regulation;
  - closure considerations.

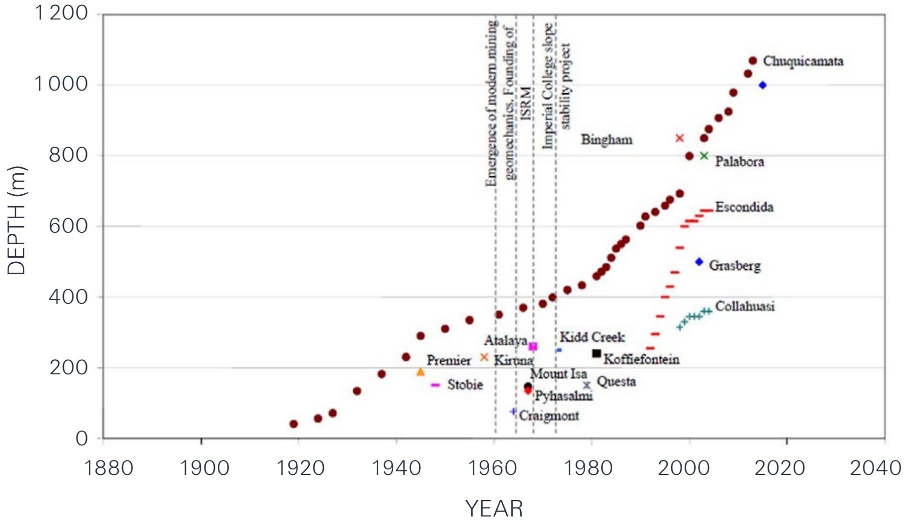
Above: Bingham Canyon Manefay Slide. Complete destruction of the highwall, haul road and part of the heavy vehicle workshop.

Below: The Koolan Island iron ore mine was closed after the seawall collapsed.

Sources:
Above: Rio Tinto. Below: Mt Gibson Iron Ore

Understanding the risk

As near surface, higher grade orebodies are exhausted and larger machinery with greater automation come into use mining is moving to exploit ore bodies at greater depth and with greater geotechnical complexity. This is leading to a increase in open pit depth with pit slope sin excess of 1 000m, deeper underground mines and the use of mass mining (Sub-Level, Block and Panel Caving) techniques all of which increase risk of geotechnical instability.



Open pit mine planning considering geomechanical fundamentals (Andrés Parraab, Nelson Moralesa,b, Javier Vallejosb and Phu Minh Vuong Nguyena)

Above: Palabora open pit failure. Due to undetected fault structures the wall of the open pit failed following the initiation of the black cave beneath the pit. The failure eventually destroyed the haul road in the neighbouring Foskor Operation.

Below: The results of a rockburst in an underground mine in brittle rock subjected to very high stresses.

Sources:
Above: Author's collection Below: Practical Rock Engineering – Evert Hoek

Examples of Notable Geotechnical Losses

Bingham Canyon – 2013
Manefay Slide. Failure on a fault destroyed high wall, haul road and Heavy Vehicle Workshop followed by a second run out of material which buried and damaged mining equipment at the far side of the pit. No fatalities.

Northparkes Lift 1 – 1999
Plug failure of cave back to surface following stalling of the block cave propagation. Air blast damaged underground infrastructure and killed four people.

Mt Gibson – Sea Wall failure – 2014
Koolan Island main pit seawall failed flooding the open pit following high tides. Around 200 workers were made redundant following the failure, with operation later placed in care and maintenance. USD 64m cost to the insurance market.

KCGM – Eastern Wall failure – 2018
Failure in Golden Pike area destroyed Y-ramp haulage. Change of mine plan and delay of 3.5 years accessing high grade ore.

Grasberg Mine – Big Gossan Mine – Fall of Ground – 2013
28 miners killed and 10 injured in fall of ground in training chamber due to weathering of limestone.

Vedanata – Gamsberg Pit Wall failure – 2020
Failure of southern wall of the pit. Two people killed and multiple pieces of plant buried and destroyed. Approximate 20% production loss predicted in 2021/22.

Newcrest – Kencana – 2016
Underground seismic event damaged multiple mining level leading to six months complete loss of production.

Managing the Risk – Best Practice

Geotechnical Design and Construction

- Geotechnical design
  - Continuous review with multiple different parties contributing to the design process
  - Feedback from Geotech monitoring instruments and observations fully incorporated in the mine design updates with solid procedures and audits

- Hydrogeology
  - Fully mapped and understood hydrogeological conditions

- External consultants / review boards
  - External Geotechnical review board. Yearly assessment and report All recommendations followed

- Design compliance
  - Detailed design compliance in place, full records kept and solid auditing procedures, over 95% compliance

Geotechnical Condition Monitoring

- Ground control plan, mining QA/QC
  - Field geotechnical staff verifies and update conditions on a daily basis.
  - Geotechnical conditions properly classified and assessed.
  - Redundant geotechnical monitoring.
  - Excellent instrumentation.

- Surface mining particularities
  - Redundant radar monitoring, laser and prisms.

- Underground particularities
  - Geotechnical staff on each development area.
  - Roof support pre-designed for each geotechnical condition.
  - LiDAR system employed for underground deformations

- Mining induced seismicity/subsidence
  - Extensive online seismic instrumentation around the mine workings and infrastructure.
  - For caving operations, extensive monitoring on cave or subsidence development including:
  - Network smart markers
  - Cave tracker beacons
  - LiDAR scanning
  - Affected areas mapped 3 to 4 years in advance

Key message

Geotechnical instability and failure can have serious consequences for a mining operation including loss of life, disruption to operations through loss of access, increased cost of working, sterilisation of ore, clean up costs, cash flow interruption, reputational damage, loss of equipment, environmental impacts, regulatory compliance issues and further permitting issues. Worst case situations can end up with the operation having to close.

Excluding NatCat Swiss Re's experience of claims over the last ten years (2011–2021) shows 7% of our claims are geotechnical related however they account for 31% of the claims value paid.

In order to avoid or minimise geotechnical issues mines should make sure they understand prior to mining the rock mass response to mining (in both the near field and far field), use appropriate designs and techniques and undertake continuous monitoring and improvement of the designs during mining.

Contact:
Contact your Swiss Re Corporate Solutions Risk Engineer, broker or representative for additional information or assistance