Rock engineering
Quantifying safety and economic risk

Rock variability makes the job of designing excavations a difficult one, with its own design methodologies that set it apart from the work that civil engineers do with concrete, steel and other engineered materials. As a natural substance, the variability of rock also means that a high degree of investigation and monitoring is necessary during the excavation process and throughout the life of the excavation.

Predicting and controlling rock behaviour - the daily responsibility of a rock engineering specialist - has a direct bearing on the safety risks and broader economic risk of any mining project.

The role of a rock engineer is particularly important in the context of South Africa's gold and platinum mining industries, where the narrow, tabular reefs demand highly labour-intensive operations and make it difficult to distance workers from hazardous areas to minimise the risk of injuries.

Rock variability makes the job of designing excavations a difficult one, with its own design methodologies that set it apart from the work that civil engineers do with concrete, steel and other engineered materials. As a natural substance, the variability of rock also means that a high degree of investigation and monitoring is necessary during the excavation process and throughout the life of the excavation.

Indeed, even before an orebody can be considered as mineable, mechanical modelling of excavations in the rock mass needs to be performed, which includes the geology, geological structure, groundwater and rock stress.

As the mine develops through the project levels from design to construction and operation, and more data becomes available, the detail of modelling will increase. Once a mine begins development - even before it gets to mining ore - the rock mass in which the excavations are constructed must be monitored to check that the rock is responding to the excavations as predicted in the design. Geological conditions unforeseen in initial investigations should be identified during excavation so as to prevent instability and manage it where it does occur.

SRK's experience in geotechnical investigation, design and related research has led to the development of its own methods for quantifying the economic and safety risks in underground and opencast mines. Computer-based modelling is a key tool in this complex process.

Data on the geometry of excavations, the material properties of the rock and the stress field are analysed using sophisticated software, which allows the simulation of changes in rock behaviour in a sequence over time. Modelling varies from simple two-dimensional calculations that can be done in a few hours to sophisticated three-dimensional models that can take several months to develop, depending on the rock mass conditions and the requirements of the excavations. Several different numerical modelling codes are available and each has different functions and uses.

Elastic modelling - commonly used in deep, underground mines - is computationally simpler, enabling more detailed and complex mine geometries to be simulated. It is possible to simulate all the excavations in an underground mine with these codes. The objective is simply to determine the stress distribution around these excavations, which allows the rock engineer to determine the potential for stress damage and seismicity.

More sophisticated non-linear modelling codes are used to simulate failure of the rock surrounding excavations; these are often used for slope design or underground excavations in weak rock. Due to their increased complexity, more time is required to solve mine geometries. These models are used to obtain a deeper understanding of the behaviour of the rock surrounding excavations, but are generally limited to simple mine geometries.

The various elements that affect the stability of an excavation can only be accurately modeled if there is enough detailed information gathered from investigations. If the information is limited, then the rigour of the model will be limited.

It is often the geological conditions that have the biggest effect on stability, but this information is the most difficult to acquire. That said, the complexity of the problems faced in rock engineering is often beyond the capabilities of even the newest computers.

It is job of the rock engineer to simplify the problem into a model that is practical to run, but includes all the necessary details that are relevant for the stability of the mine. To ensure that excavations remain safe and operable, ongoing monitoring is
vital. In underground mines, this includes seismic monitoring as well as tracking the movement of the rock mass from within the excavations. Open pit monitoring varies from simple visual inspections, to robotic survey instruments, three dimensional laser scanners, radars and even the use of satellite interferometry (techniques that superimpose waves – usually electromagnetic waves – to extract information about them).

In summary, the role of the rock engineer is to ensure that excavations are designed in such a way that will reduce the potential sources of hazards, which can be induced by prevailing geological conditions or in the process of mining the excavation. It is also the role of the rock engineer to work alongside the mining teams, to ensure the rock engineering designs are adhered to; this means they need to constantly check whether the rock mass conditions do not change outside of those anticipated in the design, in which case the design will be revisited and adjusted.

SRK provides rock engineering services to both open pit and underground mines in South Africa and globally. In addition to this commercial involvement, SRK plays an active role in developing the discipline of rock engineering in the country. SRK employees are involved in the South African National Institute of Rock Engineers (SANIRE), which includes organising several international and local rock engineering conferences and in the examination of rock engineers. SRK is also active in many research projects under the mine health and safety council, and has seven employees enrolled for MSc degrees with a research component and three employees in various stages of Doctoral studies.

Contributors: William Joughin partner and principal mining geotechnical engineers SRK Consulting (SA) and Robert Armstrong principal geologist (geotechnical) SRK Consulting (SA)