Summary

This project has developed improved criteria, guidelines and the use of numerical models to design mine layouts at depth. Bracket pillars, strike-stabilizing pillars, concrete pillars, backfill and caving were all studied, using a range of numerical techniques. Data from seismicity, GPR, seismic tomography, wire extensors, stress measurements, fracture mapping, closure-ride stations and precise levelling were used and interpreted. New Mine design criteria were introduced.

Design charts for bracket pillar design were developed to provide rock mechanics engineers with an initial estimate of required bracket pillar width based on mining and geological factors that are easily measured. The rock engineer must also decide on a tolerable event magnitude that could take place on any geological feature. This is less conservative than requiring zero ESS, as was previously suggested. As the design charts are based on assumptions that cannot cover every case, they are meant for initial, comparative, assessment.

Figure 1: Maximum relative normal velocity in the stope for various approaching angles to a discontinuity.

Rock engineering and geological data were compiled for numerous dykes and faults in a relational data-base to assist in determining relationships between their characteristic properties and in situ behaviour.

A new method has been developed to improve the relative locations of seismic events with similar mechanisms. These methods can be used to identify different source mechanisms within diffuse “clouds” of seismicity.

The ERR concept has been extended to include the energy released while the on-reef stress is limited to a pre-defined value. A computer program, MINF, reads MINSIM mining pattern files and implements this concept on shaft-sized mining layouts.

Criteria for regional support should be presented in terms of probabilistic concepts. This approach falls out of the scope of the current project and has not been pursued.

A conceptualised design process for stabilising pillar layouts has been proposed.

Conclusions

- Dynamic modelling suggests that a minimum angle of 35° should be maintained between a longwall face and a seismically active discontinuity (Figure 1).
- Many stabilizing pillars yield seismically when stress is imposed on them at Average Pillar Stresses (APS) perhaps as low as 250 MPa. The pillar size or spacing did not significantly influence the back-area seismicity. Further deformation is reduced when substantial load is taken in the back area.
- Large lead-lag gaps between longwalls separated by strike pillars should be avoided. It is recommended that no more than one-year face advance interval should exist between two consecutive longwalls.
- The presence of geological discontinuities in the pillars has a small effect on the total seismicity, whereas pillars with irregular pillar generate much more seismicity than those with regular shapes.
- Values obtained from re-surveying of footwall excavations was fairly well predicted by elastic modelling. Greater inelastic effects at the skin of the excavation have been recorded for deeper tunnels than shallower tunnels.
- Elastic and inelastic modelling was used to show that ERR was reduced by 15% by replacing 40 m rock pillars by 56 m concrete pillars well placed in advanced headings.
- The use of a plasticiser in concrete significantly increased its peak strength.
- Inelastic modelling showed that the foundations yielded for both rock and concrete pillars.
- An in situ trial concrete block, of width to height ratio about 4.6, provided the necessary information to conclude that the block was stable under sustained static loading and repeated seismic loading. The value of Young's modulus was similar to that measured in the laboratory.
- Caving at Hartebeestfontein mine is now well understood. In the back area, it is as effective as backfill for regional support.
- A detailed list of conditions favourable for and of conditions not suited to the application of cave mining has been compiled and circulated.
- A new mine design criterion to evaluate the relative merits of different mine layouts, the “Rockburst hazard index” (RHI) was evaluated and presented to rock engineers. RHI is based on a combination of ERR and variants of the ESS criterion. RHI is implemented as a program which runs on personal computers under the Windows™ operating system.
- ERR using a limit of 250 MPa to the on-reef stress provided an improved predictor of the spatial distribution of seismic activity was provided by ERR that assumes elastic behaviour of the entire rock mass. It is suggested that pillars deform seismically long before APS values of 600 MPa area reached.
- The influence of backfill on regional support is still not conclusive as data from limited times period and a narrow range of percentage of backfill (40 to 60%) were considered.