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Mechanisms of rockmass behaviour associated with slope instability

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ABSTRACT

Many open pit mines are now being mined at very significant depths, often at depths far greater than was originally planned. Even deeper open pits are also being planned, to depths that would be considered deep by underground standards. Major rock slopes or high rock slopes result from deep open pits. The heights of the resulting rock slopes are usually beyond the current experience and knowledge base. Present understanding of the mechanisms of slope behaviour and failure for high slopes, and for slopes subjected to high in situ stress conditions, appears to be lacking. If the mechanisms of slope behaviour are not well understood, the validity of commonly applied methods of analysis of the stability of such slopes may be questionable.

The economic impact of excessively conservative design or of failures in these slopes can be very large. A major failure, apart from its immediate effect on production, could result in loss of ore reserves and can cause premature closure of the mine. Slope failures of any kind, if not properly managed, can represent a safety hazard for mining personnel. Large scale failures may also affect the surface surrounding the open excavation, which may involve structures and infrastructure. It is said that the optimally designed slope is one that fails the day that mining ceases. Slopes that do not experience some form of failure are said to be overdesigned.

This dissertation details the research that has been carried out into mechanisms of failure of slopes in discontinuous, hard rock masses. UDEC modelling code was used to model rock slopes in which variability occurs in the geometry of the geological planes of weakness. The aim was to determine how sensitive the mechanisms of failure of the slopes are to this variability, a variability that can typically occur in rock masses. The results of the analyses have important implications for the validity of methods of slope stability analysis commonly used for prediction and assessment of stability.

The range of numerical models analysed has shown that the behaviour can differ significantly from one model to the next. In particular, the variability in the geometry of the discontinuities introduced into the models can have a very significant effect on the behaviour of the rock slopes. This is in spite of the fact that the rock masses being modelled can be considered to be statistically the same. In nature, the variability will probably be greater than that considered in

the modelling. It is necessary to take this variability into account for realistic analysis and prediction of rock mass behaviour.

The analyses show that the rock slope deformations and failure did not involve a single failure surface, but are progressive, with deformation and local failure taking place throughout the slope height. In no case did failure involve displacement on a single failure plane. This places in question the conventional limit equilibrium approach to stability analysis, in which the stability of a failing mass above a defined or assumed failure surface is evaluated. No such surface could be defined for any of the models analysed. If such a failure surface was to be determined from the observations after failure, it would not be correct. The usual back-analysis approach to determine rock mass parameters is therefore also in doubt, since it will probably not take into account the actual rock slope failure mechanism. Therefore, although back analyses are considered to be important, the use of this approach could result in incorrect strength and deformation parameters for the rock mass and shear surfaces.

From the results of the analyses carried out, the following conclusions can be drawn regarding the deformation and failure of rock slopes in a systematically jointed rock mass:

- Deformation and failure will not be confined to specific failure surfaces, but will occur progressively throughout the mass. Multiple mechanisms of failure will occur, including shear and tensile failure on discontinuities, and shear, tensile and extensional failure of intact rock material. The accumulation of these types of localized failure will ultimately result in slope failure.
- Knowledge of the orientations and spacings of discontinuities in rock slopes does not allow prediction of a unique failure surface. Except in very specific situations, such a unique failure surface is unlikely to occur.
- Realistic prediction of real jointed rock slope behaviour is only likely to be possible using probabilistic approaches that take into account the variability in the rock mass.