Fifth Australia-New Zealand
Conference on Geomechanics
Sydney, 22-23 August 1988

Open Cut Mining - General Report

J. TRUDINGER

1 INTRODUCTION

The six papers which are reported in this session address a variety of topics and concerns relating to the stability of open cuts. Of these papers four address coal mining situations; one examines failures in two clay pits; and the other contributions deal with evaluation of strength parameters and methods of analysis. However, both of these papers have used examples of actual mine rock masses to develop or to demonstrate the analytical techniques. Thus, all papers reflect the application of research to actual field problems.

Five of the six papers use back analysis procedures to assess strength parameters. Another aspect which was recognised by all authors was the significant influence of groundwater on the stability of open cuts.

2 REVIEW OF PAPERS

Piper discusses two quite different failures through clayey soils. In one of these cases, failure was ascribed to translational sliding along a bedding plane in a siltstone rock mass; the other failure was of the slip circle type and occurred through kaolinitic clayey sand residual soil derived from weathering of granite. In both cases groundwater appeared to contribute to the failure.

I am intrigued at the "Computed critical failure surface" which Piper shows on Fig. 1. of his paper. Rather than representing a translational failure along bedding as the author states, the surface which is shown appears to more closely resemble a slip circle with most of the failure surface across the fabric of the rock mass. A plane sliding analysis may therefore have been more appropriate, given the field evidence.

For the failure through kaolinitic clayey sand soil, Piper suggests that residual shear strength governs the behaviour of the slope, as these strength parameters appear to fit the back analysis. However, there may be at least one additional explanation. Piper mentions the presence of "pre-existing fissures in the soil mass". It seems plausible that water filling or partially filling such fissures could contribute to slope failure.

The paper by **Dunbavan & Driver** illustrates, among other things, a frequent problem in stability assessment, namely the existence of unsuspected, unfavourably oriented geological structure. This is a recurring theme among case histories and illustrates both the desirability of good engineering geology and the necessity to recognise that, in a mining situation, it is seldom possible to carry out a sufficiently comprehensive investigation to ensure that all significant geological features have been identified. Fortunately, as the authors point out, the mining situation differs from the typical civil engineering case, as instability does not necessarily lead to serious problems.

Another common problem highlighted by these authors is the difficulty of achieving, under operating conditions, what were intended to be practical and straightforward remedial measures. This is another recurring theme in case histories and suggests a need for closer co-ordination between geotechnical specialists and those mining personnel who have production responsibilities.

The paper by **Newcomb, Pilkington & Raisbeck** reflects the wealth of data and experience gathered in the major Latrobe Valley open pits over more than 20 years. The role of horizontal drains in lowering groundwater levels has been clearly demonstrated. A comprehensive geotechnical monitoring programme has been implemented and is being used to provide feed-back during operations. The Boundary Element modelling method represents a powerful predictive tool. I would be interested to learn how well the movements experienced to date compare with predicted movements at the same stage of excavation.

I am particularly interested to know more about the large horizontal strains that accompany stress relief. Do joints open up parallel to the free face? If so, do these joints result in increased mass permeability and therefore more effective dewatering? Or alternatively do open joints increase infiltration, potentially aggravating the problem?

Seedsman, Richards and Williams present a convincing case to support the hypothesis that at least some spoil pile failures in the Bowen Basin are related to the existence of undrained conditions within the spoil. The authors distinguish such failures from those which occur along pre-existing sheared zones underlying the spoil. The fact that these undrained failures occur rapidly means that they are potentially very significant to maintenance of safe mining operations. The authors recommend "long term settlement and compaction of spoil" in addition to good pit cleanup and dewatering. The former recommendation would be difficult and expensive to achieve in most operating situations. However, this paper makes a case that operators should not ignore in situations where rapid spoil pile failures could threaten life or property.

Gray observes that rock slope failures, in his experience, almost always occur where structural or other discontinuities "daylight" at or near the toe of the failure. While this is well-recognised in the case of strong rocks it is commonly overlooked in weak rocks and soils. There is a tendency for structural discontinuities in weak materials to be overlooked, possibly because they are not clearly evident in soil samples, but possibly also because many practitioners believe that the strength of the soil substance is the main factor influencing stability.

In many of our mining operations, there is a deep zone of extremely weathered material which contains patterns of intersecting discontinuities similar to those of the underlying parent material. Even younger alluvial soils which have not experienced a comparable history of tectonic stresses may contain extensive discontinuities (Stapledon, 1970), which can lead to failures in slopes which would be quite stable were discontinuities absent.

Gray has effectively used back analysis techniques to evaluate in situ cohesion values for rock slope failures. He has also demonstrated good agreement between strength parameters obtained from laboratory shear tests carried out using appropriate test procedures and parameters obtained from back analysis.

The significant change in direction of movement of the Saxonvale East Wall failure is interesting. Gray postulates that the initial failure direction was caused by the maximum horizontal stress and by water pressures acting normal to the main joint direction. The movement vectors shown in the paper indicate an abrupt change in the direction of movement following a three month period during which there was 20 to 50mm of lateral displacement. This suggests to the reporter that the direction changed after the slide mass had passed beyond some constraining feature on one of the failure boundaries. More detailed geological information would be useful in evaluating the mechanisms involved in this failure.

Priest & Samaniego offer a statistical approach to evaluating face stability of excavated slopes in jointed rock masses. This approach uses computer generated discontinuities which are derived from statistically defined discontinuity characteristics. In repeated analyses, the authors observed a wide range of stability indices for the same slope with different random realisations generated from the same discontinuity characteristics. This in itself appears to limit the applicability of the approach as a predictive technique. However, the method is promising as a tool to examine the sensitivity of a slope to changes in various parameters.

The authors note that unfavourably oriented, persistent discontinuities control block behaviour at the Koolan Island mine where the approach has been applied. Similarly, commenting on the results of the stability analyses using computer generated discontinuities, the authors observe that "the chance occurrence of just a few large unstable blocks will always dominate face stability".

3 NOTABLE OMISSIONS

The papers reported in this session do not represent the full scope and range of current geotechnical practice in Australia relating to the stability of open cut mines. Apart from an example by Dunbavan & Driver of the use of shear pins at the Riverside Mine, rock reinforcement receives little mention. Yet there has been a virtual revolution in the use of rock reinforcement in recent years. Similarly, the effect of blasting on slope stability, which has been featured at other recent conferences and which remains an important operating issue, is not mentioned in the papers in this session.

Another notable omission of concern to this reporter is the absence of engineering geological input to this session. It is to be hoped that this situation is anomalous and does not indicate a diminishing role for engineering geologists in slope stability studies.

4 RESEARCH NEEDS

The papers in this session, either directly or indirectly, raise a number of issues that warrant further investigation and research. Examples are given below:-

4.1 Stress Relief

While the existence of high horizontal stresses is well known and the effects of stress relief are commonly observed, the detailed behaviour of an unconfined rock mass undergoing stress relief does not appear to have been well researched and documented. It would be useful if practitioners could have at least some empirical information to assist them in predicting the effects of stress relief on the shear strength of discontinuities, and on rock mass permeability. It would also be useful to have information concerning the manifestations of stress relief that occur under differing discontinuity orientations and frequencies, and in cases where the rock mass is disturbed by blasting in contrast to situations where blast damage is minimised.

4.2 Analysis of Geological Structure

In some situations, our analytical capabilities exceed our ability to define the geological model to be analysed.

In large open cut mines, the inability to economically define the geological model to enable realistic deterministic analyses to be carried out, has led to the development of statistical methods. There is a need for refinement of discontinuity survey techniques to discriminate between persistent and non-persistent discontinuities. While it is relatively simple to discriminate given large exposures in an open pit, there is a need for techniques that could discriminate between different types of discontinuities intersected in drill holes.

Also, there appears to have been relatively little research applied to the phenomenon of rock mass jointing. While the relationships between discontinuity orientations and the principal stress directions are understood in broad terms there appears to be no theoretical basis for prediction of uncommon orientations.

Similarly, the spatial characteristics of discontinuities are not well known. Priest & Samaniego's paper makes assumptions about the extent of discontinuities which may be appropriate for the type of analysis involved. However, in many situations it is necessary to make a judgement of continuity in a third dimension (behind the face), based on a two dimensional exposure.

4.3 Innovative Stabilising Techniques

Blast damage to a rock mass behind a slope can contribute to instability. However, I have also seen cases where dislocation of a rock mass by blasting appears to have reduced the potential for sliding by interrupting the continuity of potential failure planes. Is it unrealistic to suggest that blasting operations could be designed with this objective in mind? Similarly, the use of blasting or hydro-fracturing could become routine for increasing rock mass permeability, by increasing the interconnection between water-bearing discontinuities, thereby increasing the efficiency of dewatering systems.

5. REFERENCE

STAPLEDON, D.H. (1970). Changes and Structural Defects Developed in Some South Australian Clays, and Their Engineering Consequences. Symposium of Soils and Earth Structures in Arid Environments, I.E. Australia, Adelaide.