Mechanics of Jointed and Faulted Rock, Rossmanith (ed.) © 1990 Balkema, Rotterdam. ISBN 90 6191 155 9

Utilization of the block generator 'Resoblok' to complex geologic conditions in an open pit mine

H. Baroudi, J. P. Piguet, C. Chambon & M. Asof
Ecole des Mines de Nancy, France

ABSTRACT : As part of the methodological study concerning the block modelling techniques in mining applications, a study was carried on, in an open pit uranium mine. A geological data collection of several benches shows the presence of a large sets of discontinuities corresponding to complex tectonic episods. Each set of discontinuities is characterized by statistical distribution of parameters. Those data have been introduced in a block generator software (RESOBLOK) which reconstruct the three dimensional block structure. RESOBLOK allows to take into account the tectonic episods, when identified. Different simulations can be achieved, the problem of the large number of simulations will be discussed. The block data base generated with RESOBLOK was used as an input to the Block Stability Analysis (BSA) program. BSA uses advanced "single block stability" algorithms. This study allowed to classify the benches and to qualify the instability risks. So that the miner got an idea of the action : monitoring and/or reinforcement. This methodology was found more interesting than the classical methods to study the benches stability in an open pit mine.

1. INTRODUCTION

In open pit mine exploitations, the stability of the slopes can be considered from the aspect of the full slope or from the aspect of a bench. In the first case the dimensions are selected so as to guarantee long-term stability, taking into account the ultimate dimensions of the pit. For such design, several methods exist (HOEK & BRAY, 1981) depending on the mode of failure (plane failure, circular failure ... etc).

As for the benches, their dimensioning depends on the angle of the final slope and also on the mining method (HANTZ, 1988). Often the angle of the bench is high (more than 60°), thus encouraging local instabilities which demand adequate measures : trimming, reinforcement. When the rock mass is fissured, unstable blocks may appear according to the geometrical conditions and the distribution of the network of local discontinuities. Also in the discontinuous rock masses in order to study the stability of blocks on the bench scale, techniques of stereographic projection allow a qualitative approach of the problem. Nevertheless, these techniques are not well adapted when the sets of discontinuities show a certain spatial dispersion.

The methodology to study block stability in a fractured mass, we describe in this paper is being tested and improved. This methodology is based on block modelling techniques which have been greatly developed in recent years.

The proposed approach will be applied to the case of the open pit mine at Bertholène (France).

2. METHODOLOGY FOR ANALYSING BENCH STABILITY

2.1. Introduction to the site

The open pit mine at Bertholène (in the Massif Central) has been exploited, since 1983, by the Total

2.4. Analysis of the Stability of the Benches

Before examining the stability of the two zones previously modelled, we shall briefly describe the principles of the method of stability analysis adopted.

2.4.1. Principles of the Method

The method is fundamentally based on Warburton's algorithm (WARBURTON, 1981), analysing the stability of single block. This analysis is carried out in two steps :

Geometric Analysis : tests the geometrical configuration of the fixed faces initially in contact with the block whether they permit it to move. If so the direction and the nature of the movement are determined

Mechanical Analysis : in the case where the block is removable, a safety factor is calculated indicating the likelihood that such movement will be prevented by friction. Thus, three types of movements are possible: Direct fall, plane failure, or wedge failure.

This algorithm was supplemented in order to allow for rotational motion (tilting) of the blocks (LIN & FAIRHURST, 1988).

The BSA (Block Stability Analysis) programme thus designed (ASOF, 1989), depending on the block generator RESOBLOK, makes it possible to analyse the stability of blocks by several iterative processes : when a block is unstable in the case of a given step, it is removed from the assemblage of the blocks and the analysis is carried out with the new geometrical conditions produced.

2.4.2. Characteristics of the Joints

According to the different tests, the rock (granite) has a cohesion (c) of between 13 and 45 kPa, and an angle of friction (φ) of between 30° and 40°. In order to obtain some characteristic properties of the joints, we analysed, a posteriori, a local instability. This is a wedge failure, over the planes 124°E70° and 178°W64°, the bench orientation is 50°NW80°. The

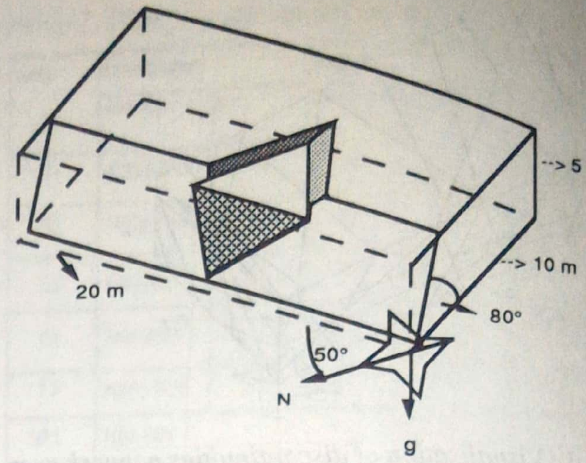

Fig. 3 : *Local instability , wedge failure*

wedge formed has a volume of about 6 m^3 (figure 3). Back analysis of this rupture, using BSA, enable us to obtain several couples of values (c,φ) corresponding to a safety factor (F) equal to 1. Among the latter, the couple adopted for this study of stability is c = 25 kPa and φ = 30°, values approaching the properties of the rock.

In order to complete further the results of the back analysis, tests on the joints are planned using the methods of BARTON in situ and laboratory experiments (HOMAND et al., 1990).

2.4.3. Stability of the Bench AB

The geometric model of the bench AB was described in the previous chapter. Stability analysis with BSA was carried out using 50 simulations, all the blocks were found to be stable. In effect, the orientation of the different sets seems favourable to stability, including that of the flat structures. This corresponds with what was observed on the site.

2.4.4. Stability of the Bench CD

Results

For 50 simulations BSA has, among other things, made it possible to calculate the total volume of unstable blocks (F < 1). The distribution of these volumes is shown in figure 4, the mean value (m) obtained is 4.54 m^3 with a standard deviation (σ) of

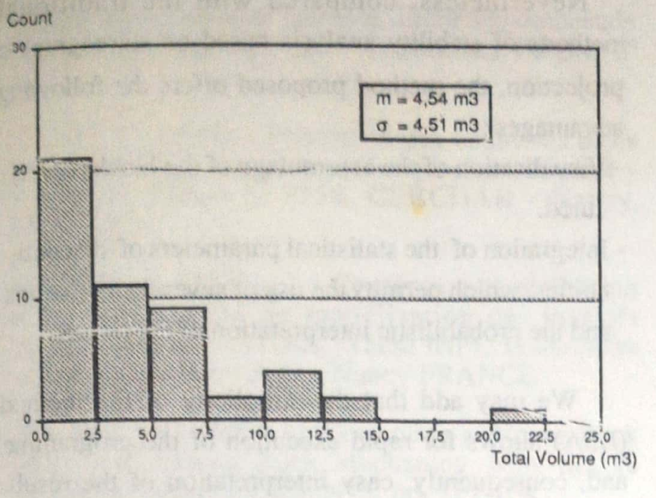

Fig. 4 : Distribution of the total volume of unstable blocks (F < 1) for 50 simulations

$4.51\ m^3$. The distribution obtained obeys an exponential law of parameter λ :

$$\lambda = \frac{1}{m} = 0.22$$

The validity of this adjustement can be easily verified by comparing m and σ, which are equal in the case of an exponential law.

The probability (α) of having a volume of unstable blocks of more than V_o is :

$$\alpha = \text{Prob}\{ V \geq V_o \} = \text{Exp}(-\lambda * V_o)$$

Thus, if we estimate that the "critical volume" is 10 m^3, there is an 11% probability of having a greater volume of unstable blocks. Very obviously, the idea of "critical volume" is difficult to estimate and demands more investigations on the site to enable us to give it real significance.

Choice of Interpretative Variables

The variable "total volume" of unstable blocks, using the probabilistic approach previously introduced, enables us :

- to compare different benches from the aspect of stability.
- to optimise the orientation and the slope of a given bench, calculating different probabilities for a given critical volume.
- to quantify, comparatively, the eventual reinforcing pattern of the bench.

Thus, this variable is of especial interest for comparing different situations. Other variables, such as the "volume of the largest unstable block", could introduce complementary elements of analysis.

Optimum Number of Simulations

In the stability analysis of the bench CD, 50 simulations were considered. However, the question that we may ask ourselves is : How many simulations must be used for such a stability study ?

In order to answer this question, let us define the variables :

V_i : Total volume of unstable blocks of geometry i corresponding to the simulation i.

A_n : Average of the V_i volumes in the case of n simulations.

σ_n : Standard deviation of the V_i volumes in the case of n simulations.

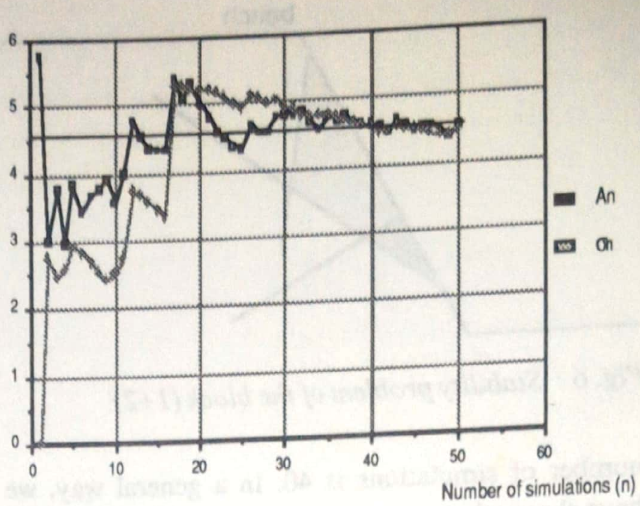

Fig. 5 : Optimum number of simulations

Figure 5 shows the evolution of A_n and σ_n as a function of n. From 40 simulations onwards, the variable A_n tends towards a limit A, close to 4.5 m3, and the variable σ_n tends towards a limit σ, close to 4.5 m3. We may therefore consider that the optimum

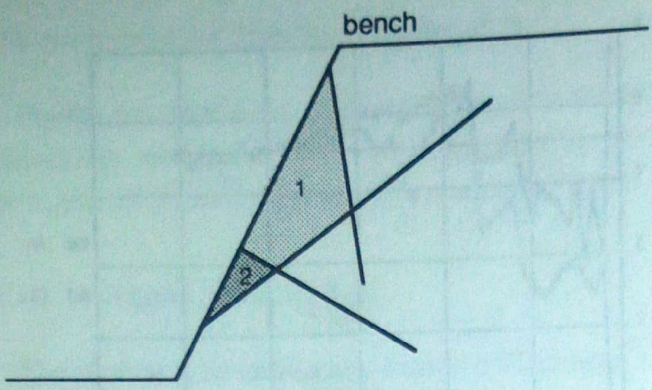

Fig. 6 : Stability problem of the block (1+2)

number of simulations is 40. In a general way, we have shown that :

$$-\frac{3}{n+1} \leq \frac{A_{(n+1)} - A_n}{A_n} \leq \frac{1}{n+1}$$

For 40 simulations an error of about 5% is committed as to the parameter A. This procedure must be reviewed if one is considering other interpretative variables.

3. CONCLUSION : CONTRIBUTION AND LIMITATIONS OF THE METHOD

The main criticisms of the proposed procedure are inherent in the method for analysing the stability of single block. Among these criticisms are the following :

- Only the forces exerted on the plane failure are considered in the stability study. This may result in over conservative analyses.
- The fact of considering the blocks independently can conceal an overall instability. For example, in figure 6, block 1 is geometrically stable, block 2 may be stable (large slip surface), while block (1+2) may be unstable.
- No account has been taken of the stresses of confinement acting on the blocks, yet these stresses play an important part in the stability of the blocks (BRADY & BROWN, 1985), (KORINI, 1988).

Those simple observations do not enable to get an idea of the conservatism or non-conservatism of the method.

Nevertheless, compared with the traditional methods of stability analysis based on stereographic projection, the method proposed offers the following advantages :

- Visualisation of the assemblage of the blocks constituted.
- Integration of the statistical parameters of discontinuities, which permits the use of several simulations and the probabilistic interpretation of the results.

We may add that the simplicity of the method (BSA) allows for rapid execution of the programme and, consequently, easy interpretation of the result. This method may likewise constitute a first approach, making it possible to determine the critical geometric conditions to be studied by advanced methods, for example the Distinct Elements Method (ITASCA, 1989).

ACKNOWLEDGMENT

The authors would like to thank MM. DUPLAT and H. FRAISSE from Total Compagnie Minière for their collaboration and their advise during the realization of this work.

REFERENCES

ASOF. M. (1989) : Algorithme d'analyse de la stabilité d'un assemblage de blocs en 3-D (état d'avancement de BSA). Rapport interne Laboratoire de Mécanique des terrain, CERCHAR, Ecole des Mines de Nancy - FRANCE.

BLIN-LACKROIX J.L. (1988) : Analyse et modélisation des fractures et des systèmes fracturaux en milieu rocheux. Thèse INPL Nancy.

BRADY B.H.G., BROWN E.T. (1985) : Rock mechanics for underground mining. Allen & Unwin, LONDON.

CERCHAR (1989) : Notice d'utilisation de RESOBLOK Version 2.1. CERCHAR Nancy - FRANCE.

FRAISSE H. (1986) : La mine à ciel ouvert de Bertholène (Aveyron). Industrie minerale - mines et carrières - les techniques, décembre.

GENTIER S. (1987) : Morphologie et comportement hydromécanique d'une fracture naturelle dans le granite sous contrainte normale. Etude expérimentale et theorique. pp. 128-136 - documents BRGM n° 134.

HANTZ D. (1988) : Prévention des chutes de blocs en découvertes. Rapport technique 1er semestre - Recherche CECA n° 7258. CERCHAR - Nancy, FRANCE.

HELIOT D. (1988-a-) : Conception et réalisation d'un outil intégré de modélisation des massifs rocheux fracturés en blocs. Thèse INPL, Laboratoire de Mécanique des terrains, Nancy-FRANCE.

HELIOT D. (1988-b-) : Generating a Blocky Rock Mass. Int. Journal Rock Mechanics Min. Sci. & Geomech. Abstr; vol. 25, N°3, pp. 127-138.

HOEK E., BROWN E.T. (1980) : Underground excavation in rock. Institution of mining and metallurgy, LONDON.

ITASCA (1989) : UDEC version 1.5, users manual MN-USA

KABBAJ R. (1989) : Traitement statistique de la fracturation. Doc. interne CERCHAR, Nancy, FRANCE.

KORINI T. (1988) : Modélisation Tridimensionnelle par un Assemblage de Blocs Rigides du Comportement Mécanique d'un Massif Roccheux à Fissuration Individualisée en vue de l'Analyse de la Stabilité d'Ouvrages Miniers. Thèse de l'Ecole des Mines de Paris, France.

LILLIE F. (1987) : BERTHOLENE-Gisement des Balaures, Principales structures et compartimentages des tranches supérieures (MCO-niv. 710), doc TCM.

LIN D. , FAIRHURST C. (1988) : Static Analysis of the Stability of three-dimensional blocky systems around excavations in rock. Int. Journal Rock Mechanics Min. Sci. & Geomech., vol. 25 N°3.

MASSOUD H. (1987) : Modélisation de la petite fracturation par les techniques de la géostatistique. Thèse ENSTIMA, BRGM-FRANCE.

RODE N, HOMAND F, HADADOU R, SOUKACHOFF V. (1990) : Mechanical behaviour of joints in cliffs and open pits.Int. Conf. Rock Joints - LOEN-NORWAY (in press).

WARBURTON P. M. (1981) : Vector Stability Analysis of an arbitrary polyhedral rock block with any number of free faces. Int. Journal Rock Mechanics Min. Sci. & Geomech. vol. 18.