



Invitation

à la Séance Technique du 31 mai 2018

Apport de la mécanique des roches à l'exploitation minière

Rock Mechanics contribution to mining operations

Mines ParisTech, Amphi L108, 60 boulevard Saint Michel, 75006 PARIS

- 13 : 45** **Accueil des participants**
- 14 : 00** **Introduction à la thématique :**
Frédéric Pellet, Mines ParisTech
- 14 : 15** **Destress blasting as a proactive measure against rockbursts**
Petr Konicek, Institute of Geonics, Czech Academy of Sciences
- 14 : 45** **Geostatistical study of the linear Fracturing Frequency (FF) in Chilean copper mines**
Serge Séguret, Mines ParisTech, Centre de Géosciences
- 15 : 15** **Discussion**
- 15 : 35** **Pause**
- 16 : 00** **Scale and similitude considerations for reliable simulation and forecasting of large scale instability in mines**
David A. Beck and Frederik Reusch, Beck Engineering, Australia
- 16 : 30** **Modeling of fragmentation and cave propagation in cave mining**
Rima Ghazal and Daniel Billaux, Itasca Consultants SAS
- 17 : 00** **Monitoring and numerical modelling of induced and triggered seismic activity in a deep sublevel-stopping mine**
Francesca de Santis, Yann Gunzburger, Vincent Renaud, GeoRessources Nancy - Ineris
- 17 : 30** **Discussion**
- 18 : 00** **Fin de la séance**

Résumés / Abstracts

Destress blasting as a proactive measure against rockbursts

Petr Konicek, Institute of Geonics, Czech Academy of Sciences

Rockburst represents a very dangerous phenomenon in deep underground mining as well as in underground constructions in unfavourable conditions (great depth, high horizontal stress, proximity of important tectonic structures, etc.). The rockburst problem relates to the natural and mining conditions of the rock mass. It is very difficult to decide which of the factors prevails, but crucial role play occurrence of competent rock layers in the rock mass. Destressing techniques play a very important role as an active measure against rockbursts in many mining regions. The destressing techniques are a very important rockburst control techniques aim to competent rocks. The main goals of destressing are the softening of competent rock layers, reduction of strain energy storage and rock mass stress release. Destress blasting is a very important destressing technique which impacted rock mass due to explosion of explosive material in boreholes. This technique is used in ore mining as well as in coal mining for a long time and this technique was sometimes used in underground construction in non-uniform geomechanics conditions. The importance of destress blasting application is increasing with increasing mining depth and increasing competent rock layers' occurrence, as well as increasing horizontal stresses. Lecture presents background of this technique and its state of the art review. Main part of the lecture will be focused on case studies form hardcoal mining from Czech Part of the Upper Silesian Coal Basin where destress blasting technique is used for more than 30 years. Rockburst risk in this region is very high due grate mining depth (around 1000 m below surface) and high share of competent rocks layers occurrence between coal seams. Case studies will be described in details as well as arguments for using this destressing technique will be discussed widely. Stress release efficiency, as one goal of the destress blasting technique, is analysed in this region according to the registered seismicity using the authors' own methodology: seismic effect calculation. Intense rockburst impacts in deep underground constructions and their prevention in great depth and in overstressed rock mass conditions shows that possible solution of this problem could be destress blasting technique and long term knowledge from destress blasting implementation in underground mining could be inspiration in some cases for underground constructions.

Geostatistical study of the linear Fracturing Frequency (FF) in Chilean copper mines

Serge Séguret, Mines ParisTech, Centre de Géosciences

Frequency of Fracturation (FF) is used extensively by South American miners to characterize the fragility of the rock. It is also one of the important attributes used in the Rock Mass Rating (RMR) used by many operators to parameterize the reinforcement of underground structures or the stability of open pit excavations. FF is calculated from cores of soundings of fixed size (here 1.5 m) by dividing the number of fractures observed by the intact length of the sample, which can change from one place to another of the deposit, which poses a problem to map FF or evaluate it at the scale of a production block. (FF is not an additive quantity and can not be averaged directly without making mistakes). The study presented shows how geostatistics (science of spatial statistics) can solve this



problem and transform a handicap - the "crushing", the disaggregated length of the sample - in advantage for the characterization of the fragility of the rock. "

Scale and similitude considerations for reliable simulation and forecasting of large scale instability in mines

Beck, D.A. and Reusch, F., Beck Engineering, Australia

Large scale instability in mines evolves from failure of essential load bearing elements within the mine: pillars, fault blocks, abutments and spans. Reliable simulation of mine stability thus requires that the connectedness and individual characteristics or all of these parts is captured. This means simulating with sufficient resolution the heterogeneity, discontinuities, the stress path and the strain softening, dilatant nature of the rock mass.

In this presentation some suggestions for reliable simulation of mines are offered, based on experience over 20 years using high resolution 3d, discontinuum non-linear models.

Some examples of mine scale simulation, calibration and integration with measured data from deep, very large mines with complex rock mechanics issues will be presented.

Modeling of fragmentation and cave propagation in cave mining

Rima Ghazal and Daniel Billiaux, Itasca Consultants SAS

Cave mining methods allow for the bulk extraction of large and low-grade orebodies in a cost-effective manner. The caving process involves undercutting and extraction of the broken rock from drawpoints. The propagation of the cave will be self-sustained as long as the broken ore is continued to be withdrawn. Arguably the most important parameter governing the performance and success of a caving operation is then the rock fragmentation within the ore column. Fragmentation dictates the size of the drawzone and influences the mass flow behavior within the cave column. Caving results in two types of consecutive fragmentations: primary and secondary fragmentations. Primary fragmentation occurs at the cave back due to induced stresses acting on the inherent discontinuities as the cave progresses upwards. Secondary fragmentation refers to the breakage of fragments once they transit down through the cave column until reaching the drawpoints. We present, first, the numerical tools to evaluate both types of fragmentation with an application on a real case study, then, a method for simulating cave propagation on a large scale with applications to cave mines around the world.

For evaluation of primary fragmentation, a numerical model is built in a 3DEC environment to represent a portion of the cave back. A sample of the veined rock mass is represented by an assembly of interlocked tetrahedra overprinted by more persistent joints introduced as a DFN (Discrete Fracture Network). The sample can be subjected to the range of caving-induced stress suggested by a caving model. The undercut is represented by an excavation below the sample. The fragment boundaries are formed of failed contacts at the level of veins or DFN. The presentation explores the role of some key parameters in the emergence of primary fragmentation (joints orientation and density, ratio between cave back stress magnitude and cohesive vein strength).

Secondary fragmentation is simulated using the REBOP software, a gravity flow emulator. This software simulates the growth of flow zones and air gap as a function of draw. Secondary fragmentation is processed by systematically reducing the size of fragments as they transit through the IMZ (Isolated Movement Zones) toward the drawpoints, using a shearing attrition model. As an



input to the model, primary fragment size is needed as well as UCS of intact rock, drawpoint layout and drawpoint schedule.

Finally, at a mine scale, using a fully discontinuum model to study cave propagation can be very time consuming. Itasca has developed, over the past 15 years, a continuum-based caving algorithm, as part of two industry-funded projects, the International Caving Study (ICS) and the Mass Mining Technology (MMT) project. The constitutive rock mass response required to represent caving was developed using strain-softening constitutive models. This algorithm is implemented in FLAC3D. It has been applied at more than 20 different projects around the world with successful comparison between predicted and actual cave behavior. Recent work to couple this algorithm to the REBOP software allows to better capture the impact of undercut and draw strategies on cave shape and stresses, dilution entry, and the potential for damaging load concentrations at the extraction level.

Monitoring and numerical modelling of induced and triggered seismic activity in a deep sublevel-stoping mine

Francesca de Santis, Yann Gunzburger and Vincent Renaud, GeoRessources Nancy - Ineris

The Garpenberg underground mine (Sweden) is a non-ferrous metal mine, owned by Boliden company. It is exploiting lead, zinc and copper, together with minor amounts of silver and gold. The study area of the ongoing research work is part of the Lappberget orebody: an almost vertical deposit, which is mainly exploited by the sublevel stoping method, with backfilling, down to 1300 meters depth.

A microseismic monitoring network, constituted by both 1-component and 3-components geophones, was installed in this area of the mine in the end of 2014 by Ineris. Recorded microseismic activity until December 2016 shows a good correlation with mining excavations, but also triggered seismic events, which are influenced by the presence of weak rock lenses within the stiff rock masses.

A 3D elasto-plastic numerical model was run with the code FALC-3D, considering a precise reconstruction of the geology, the virgin stress state and the mine voids. The model takes into account 70 excavation steps, which correspond to the drifts developed and the stopes produced in the study area between 2014 and 2016. The results show how the mining sequence, with one column of stopes being exploited upwards and downwards simultaneously, leads to high stress concentrations and to strong plastic deformation within the weak rocks.

Finally, we investigated possible statistical correlation between observed microseismic data (moment magnitude, seismic energy and corner frequency) and computed mechanical parameters (elastic and plastic deformation increments, Von-Mises stress jumps, released energy, etc.) by means of principal component analysis, helping to identify and analyze possible seismicity-triggering phenomena.