1 ROCK SUPPORT SYSTEM IN INTERACTION WITH THE ROCK

Authors: *E. Nordlund[1], D. Saiang[1], P. Zhang[1], M. H. Basarir[1], U. Nyberg[1], S. Shirzaegan[1], Westblom[1], , L. Malmgren[2], P-I. Marklund[3], A. Nordqvist[2], D. Sandström[3],*

Affiliations:[1]*LTU,* [2]*LKAB,* [3]*Boliden Mineral AB*

1.1 Background to project

Mining at greater depth implies increased stress magnitude which in turn increases the risk of instabilities in underground openings. The main design principle for rock support is to help the rock to carry its inherent loads. The objective of this project is to improve the understanding of (i) the rock mass response and the rock support system performance and (ii) the interaction between the rock mass and the rock support system with increasing mining depth for squeezing as well as brittle and rock burst conditions. The objective for the mining companies is to reduce the number of production disturbances caused by poor or unforeseen rock conditions or rock mass response, thereby decreasing the risk for personnel injury and production losses. The results from this project will be used to (i) improve the ground control strategy, (ii) develop rock support systems for squeezing (large deformations) and rock burst conditions and (iii) develop robust design methods for rock support.

1.2 Project activities

1.2.1 General

Ground control problems related to deep mining can be grouped into two extremes: (i) hard rock and mining-induced seismicity and (ii) altered weak ore contact zones within a hard host rock mass. The project is therefore divided into two sub-projects: (i) mining-induced seismicity and (ii) large deformations and squeezing conditions, respectively. The main activities in the project are (i) Numerical analyses and (ii) Field studies. The first part of the project has focused on the preparation and planning of field monitoring programmes and field tests, as well as on preparatory numerical studies.

1.2.2 Numerical studies

Malmgren (2005) showed, by 2D analyses, that the single most important factor for the behaviour of the shotcrete and the shotcrete-rock interaction was the uneveness of the surface of a drift (walls and roof). We have therefore analysed the laboratory tests carried out by Chang (1994) using the 3D Distinct Element Code, 3DEC. This study showed that it was a great difference in behaviour between a smooth surface and an uneven surface. The 2D unevenness constitutes the worst case, but the 3D unevenness shows a similar behaviour. However, the tests we simulated had a doubly waved surface, i.e., the “peaks” and "valleys" were parallel to the tunnel axis and not randomly irregular. Since a real rock surface is controlled by natural geological structures and blast damage, the unevenness is more irregular than the analyzed surface, and less similar to a 2D surface. Despite this a 2D unevenness will be used, since a model with a 3D unevenness is very time consuming to make and run. Finally we have decided to use the discrete element program, 3DEC, for the rest of the analyses, since the logic for interaction between rock and rock support is much better than in FLAC3D. A number of other numerical studies are also in progress, for example:

- 2D analyses of the field test in the Kristineberg mine
- analysis of laboratory tests
  – static tests of shotcrete and rock bolts (2 studies)
  – dynamic tests of rock support systems
- sensitivity analysis of the rock mass behaviour of the Kristineberg mine

1.2.3 Field measurements and large-scale test

In the project two field measurement programmes will be carried out, one in the Kristineberg mine and the other in the Malmberget mine. The field test in the Kristineberg mine were carried out during March 2010 in stope J10-3, cut #4 and comprised 10 rounds. Rebars and D-bolts, respectively, were used in every other round i.e., 5 rounds with rebars and 5 rounds with D-bolts. The instrumentation consisted of 4 "high density" measurement profiles, 6 "low density" measurement profiles and 2 extensometer/convergence profiles. Some observations are shown in Figure 1-1.

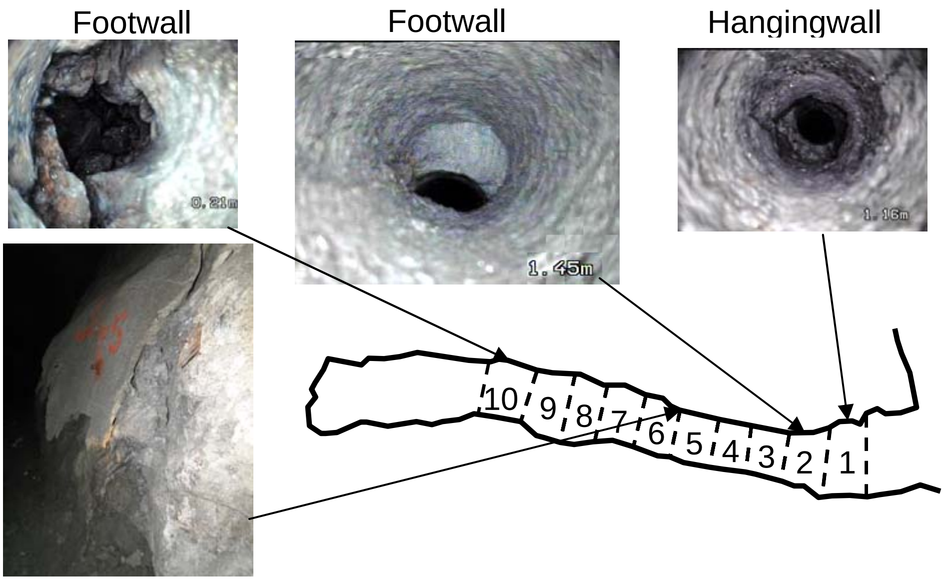

Figure 1-1 Observations in the J10-3 stope, cut #4 in the Kristineberg mine.

Mining of cut #5 has been finished and cut#6 is going on. Monitoring and damage mapping have been carried out also during mining of these cuts. The observations and measurements in all three cuts (cuts #4, 5, 6) will be used to describe the behaviour of the stope and to build and calibrate the numerical models of the orebody. The instruments will be installed during 2011 in the Malmberget mine.

A series of large-scale dynamic tests of rock support systems for seismic conditions is carried out in the Kiirunavaara mine during the 2010 and 2011 (Figure 1-2). The dynamic load is generated by detonation of explosives. During autumn 2010 and the first part of 2011, so called zero tests were carried out in order to evaluate and “calibrate” the load and to design the instrumentation for the tests. The principal idea is to simulate ejection caused by the wave reflection. To reduce the damage caused by blast gases, a military explosive, NSP 711, is used. During the zero tests we measured the gas pressure in 2 – 4 holes in order to judge if the gases could contribute to the damage, and if so, if we could separate damage caused by the dynamic load and the gas pressure. So far we have carried out 4 zero tests. In the first two zero tests we could not break the rock support and needed to increase the charge to find the critical charge leading to total damage of the rock support. The third and fourth zero test gave serious damage to the rock support panel. We may run one more zero test before we start the main tests. See rock support panel conditions after zero test 1 and 3 in Figure 1-3.

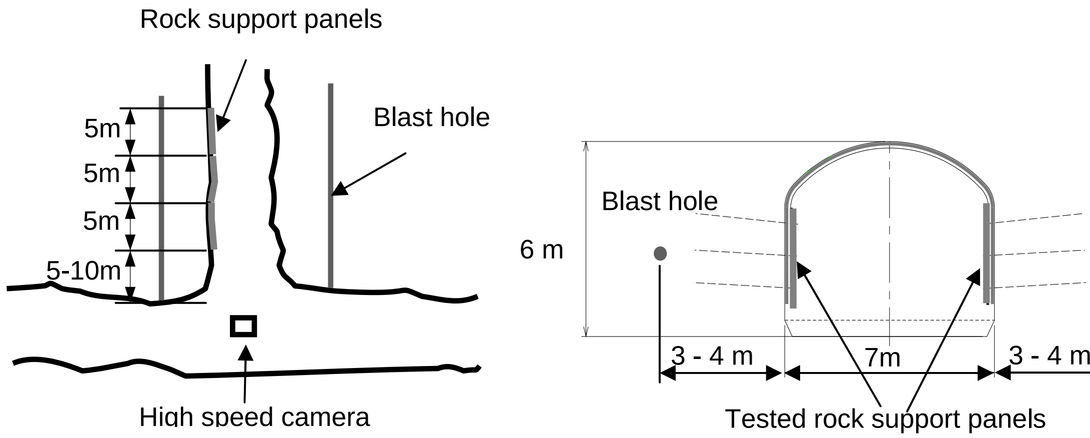

Figure 1-2 Test set-up for the main tests. The distances are approximate.

Figure 1-3 a) Panel after zero test 1, b) after zero test 3 (Photo Nordqvist, LKAB).

REFERENCES

Chang Y., 1994. Tunnel Support with Shotcrete in Weak Rock – A Rock Mechanics Study. Doctoral Thesis, Royal Institute of Technology (KTH), Stockholm, Sweden.
Malmgren L., 2005. Interaction between shotcrete and rock: experimental and numerical study, Doctoral Thesis, Luleå University of Technology, 2005:48