

Swebrec is an industrial research centre at Luleå University of Technology (LTU). It was founded Feb 1st, 2003 by an agreement between industry and LTU. The founding sponsors are LKAB, Atlas Copco Rock Drills AB, Boliden Mineral AB, Dyno Nobel Sweden AB, Kimit AB and Nordkalk AB

Swebrec is part of the division of Geotechnology of the department of Civil and Environmental Engineering but has an independent economy and its own board with members from the sponsors and from LTU. The research manager Finn Ouchterlony has a chair of detonics and rock blasting, which is paid by LKAB through an agreement with LTU. Swebrec's chairman has been Lars-Eric Aaro, LKAB (2003-2004) and Bernt Larsson, Kimit (2005).

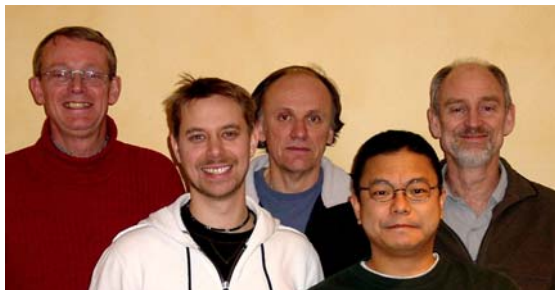
Swebrec's board Jan 1st, 2006

Henrik Grind, Nordkalk AB
 Thomas Hedberg, Boliden Mineral AB, chairman
 Roger Holmberg, Dyno Nobel AB
 Kjell Klippmark, KGS Kimit
 Andreas Malmberg, Atlas Copco Rock Drills AB
 Torbjörn Naarttijärvi, LKAB
 Erling Nordlund, LTU
 Göran Westerström, LTU

Ulf Nyberg, Mats Olsson and MSc student Daniel Johansson also work for Swebrec and there are presently two vacant positions. Dr Ioannis Arvanitidis left for Sandvik Hard Materials in 2004 and was replaced by Dr Sedat Esen who worked for Swebrec during 2005. Greg Potts was employed on a project basis during 2004-2005.



Sedat Esen, with a PhD thesis *A non-ideal detonation model for commercial explosives* from JKMRRC in Brisbane, developed Swebrec's detonics before he left for Metso Mineral Services. The position as a researcher in detonics and rock blasting is under recruitment



Finn Ouchterlony, Daniel Johansson, Mats Olsson, Hiroyuki Arai and Ulf Nyberg.

Hiroyuki Arai from National Research Institute of Police Science in Chiba, Japan spent the fall of 2004 as a guest researcher at Swebrec.

The Swebrec group has offices at Liljeholmen, Stockholm and a testing facility at FOI, the Defence Research Institute at Grindsjön. Swebrec and FOI have an agreement on the joint use of Swebrec's blasting tank and high-speed camera. This co-operation also gives valuable research contacts.

Swebrecs work has five main goals, to

- be an international centre for high-quality research in explosives and rock blasting research
- support industrial competitiveness and sustainable development
- strengthen the ties between LTU and the industry
- stimulate the teaching of rock engineering at LTU
- increase the attraction of the field of mining and rock engineering.

Research program

Swebrec has a research program with sponsors' projects, which accounts for around half of the turnover. The other half consists of commissioned research and special projects. The yearly turnover during 2003-2005 has been 4-5 MSEK.

Much of the initial work was directed at SveBeFo's research program and the EU project Less Fines.

The research program is discussed with industry in Swebrec's program board.

Swebrec's program board Jan 1st, 2006

Henrik Grind, Nordkalk AB
 Thomas Hedberg, Boliden Mineral AB
 Hans Karlström, Kimit AB
 Torbjörn Naarttijärvi, LKAB
 Gunnar Nord, Atlas Copco Rock Drills AB
 Anders Nordqvist, LKAB
 Björn Petterson, Dyno Nobel AB

During 2003-2005, the following sponsor projects have been worked on:

- *Cylinder expansion tests and work capacity*
- *Model for bench blasting and primary crusher in an open pit*
- *Controlled fragmentation in sub-level caving*
- *The ability of image analysis to measure fragmentation*

Other important projects are

- *Less Fines production in aggregate and industrial minerals industry.* EU project no GRD-2000-2554.
- *Damage zone model at TASQ tunnel in APSE.* Part of SKB Äspö Pillar Stability Experiment (APSE).
- *Faster and better tunneling.* GHRR project. Gällivare Hard Rock Research.
- *Optimal fragmentation in quarries.* Sub-project within MinBaS project no 1:2.
- *SLC small scale test support.* Sub-project within Mass Mining Technology, Sustainable Minerals Institute, Univ of Queensland.

Swebrec has also done other work for Carl Bro Teknikkonsult AB, GHRR, SKB och SveBeFo.

The project **Cylinder expansion tests and work capacity** has as a goal to utilize the explosive's energy optimally. Development engineers Dyno Nobel (Linda Johansson, Lars Granlund och Iver Hauknes) and from Kimit (Hans Karlström) have worked with Swebrec's researchers on this project

More than 60, 100 mm diameter copper tubes filled with civil explosives have been shot to emulate the situation during bench blasting or sub-level caving operations. Eleven explosives have been investigated; mainly different ANFO and bulk emulsion qualities.



The cylinder test is better at measuring the the work capacity of explosives under realistic conditions than the under water test.

The work capacity of the bulk emulsion Titan 6080 e.g. is larger that that of ANFO, despite a lower explosion energy value. Adding aluminium powder increases the work capacity of ANFO substantially but it doesn't have the same effect on a pure emulsion explosive.

In the EU supported project **Less Fines production in aggregate and industrial minerals industry** both Swedish and European industry and research organizations co-operated. It ended June 30th, 2004.



The Swedish goal was to decrease the amount of fines produced at Nordkalk AB at Storugns on Gotland. Dyno Nobel developed a technique for differentiated gassing of emulsion explosives

that was successfully tested in the field during the summer of 2003 and then implemented in production. This decreased the explosives consumption without otherwise affecting breakage and crushing

Swebrec measured how the explosive energy is utilized. In the Storugns rounds, the following partitioning resulted

- Crushing and other rock mass losses 20–40 %
- Kinetic energy of throw 10–20 %
- Seismic energy in outgoing waves 5–10 %
- Surface energy of muck pile fragments 0,1– 2 %

Among the most important results is a new fragment size distribution for blasted and crushed rock, the Swebrec[®] distribution. The present basis data contain nearly 400 sieving curves from blasting at dif-

ferent scales and 250 sieving curves from crushing. More than 30 rock types are included.

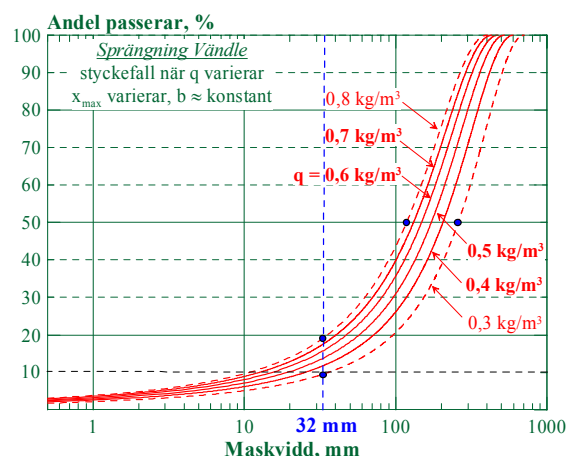
The Swebrec distribution reproduces the fines part of a blast extremely well. There is furthermore an experimental connection between the three ingoing parameters x_{50} , x_{max} and b .

Special project **Optimal fragmentation in quarries** was part of the MinBaS program. Blasting tests were made in Swerock AB's Vändle quarry outside Västerås during 2004 in order to develop a description of how the blasting result could be adapted to the desired crusher feed. The work was made in co-operation with Dyno Nobel, Hallstahammars Sprängtjänst AB and MinFo.

Two production rounds with adapted blasting patterns produced four test piles that were screened and evaluated with image analysis before the contents were crushed. The limited sieving data was used to construct the fragmentation curves in the form of Swebrec distributions.

A couple of conclusions were that

- The blast fragmentation looks like rock material curve no. 62.
- Blasting and crushing contribute about 14 % each to the road base fraction 0-32 mm.
- The sieving curves have a different form than the image analysis curves, which are judged to be less reliable.



Design curves for Vändle quarry that describe how the whole size distribution is changed when specific charge q (kg/m^3) is altered.

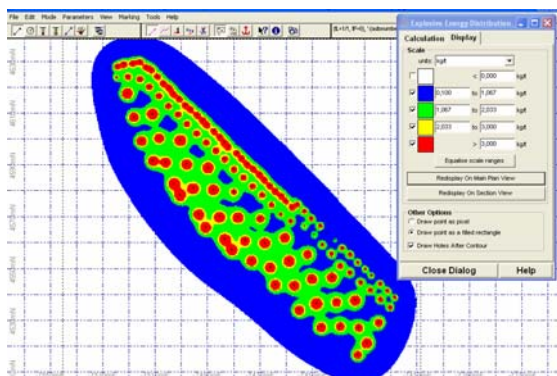
The ability of image analysis to measure fragmentation is a sponsors' project. The goal was to show that Split Desktop from Split Engineering could be used to measure blast fragmentation and to estimate the error. Split was tested on different sieved distributions.



Image analysis has methodological problems and hence difficulties to give good results in free applications like muck piles. Good results are difficult to obtain without a calibration based on sieving.

Work on the project **Model for bench blasting and primary crusher in an open pit** has been ongoing since the fall of 2004. Its goal is to develop a description of blasting in different geological areas of the Boliden Mineral Aitik mine so that the mill throughput is increased. This work has run in parallel with the mine's own M2M project.

Ulf Nyberg and Sedat Esen worked on the monitoring of round 4141-2 during summer 2005. The variation of the swelling of the charge column during gassing causes large variations in the uncharged top part and in the stemming. A more even stemming level would probably give a more even fragmentation and production flow in the mine.



Charge concentration at stemming level (Dyno)

The monitoring included a comparison of two different systems for digital image processing, the mine's own Split Online and Split Desktop. Sieving samples from the muck pile have also been used to estimate the whole fragmentation curve with Swebrec distribution. We now have better methods to do fragmentation monitoring together with Aitik's continued M2M work.

The work on sponsors' project **Controlled fragmentation in sub-level caving** was initiated during the fall of 2005. The goal is to improve the ore recovery by improving the flow properties through blasting with good, even fragmentation from round to round.

Project **Sub-level caving small scale test support** is part of the international project Mass Mining Technology with LKAB as one of the main sponsors. It started during the spring of 2005 with the goal of increasing the understanding of breakage and flow in the sub-level caving. Swebrec and Daniel Johansson, MSc student at LTU do the work.

Some 80 model cylinders of magnetite and magnetic concrete have been blasted in Swebrec's blast container at FOI at Grindsjön. Comparative shots of free cylinders and cylinders confined by debris of crushed rock are made in order to model the effect of the caving material on the fragmentation in the mine.



Cracks around water-filled hole

Swebrec has also worked on a **Damage zone model at TASQ tunnel in APSE** for SKB, the Swedish Nuclear Waste Repository Co. Mats Olsson participated in three special rounds in a 70 m long tunnel, driven to study pillar stability. Apart from the round design, the work

comprised diamond sawing and crack detection work in the walls and floor of the tunnel. One goal was to measure how much the damage zone could be reduced if the contour holes are initiated simultaneously.

In the GHRR project **Faster and better tunneling** Mast Olsson has taken part in a sensitivity analysis, risks involved and consequences of different parts of the cycle, in order to steer the future work in the right direction. The work has gone through 3 stages.

Other work

Swebrecs results are regularly presented to the industry, e.g. at the annual discussion meeting of the Swedish Rock Construction Committee, at the seminars and steering group meetings of the Min-BaS program etc.

Mats Olsson has participated in the courses held by Bergutbildarna and Finn Ouchterlony in the international courses held by Dyno Nobel and in the internal Atlas Academy training courses held by Atlas Copco. Finn Ouchterlony lectures on rock blasting at LTU and KTH.

Finn Ouchterlony is a member of the editorial board of the Int. Journal of Rock Mechanics and Mining Sciences, of the intl advisory board of the Int. Journal for Blasting and Fragmentation, of the intl organizing committee of the Fragblast conferences and of the technical committee of the EFEE conferences.

He has been the member of thesis committees for dissertations at Ecole des Mines de Paris and Universidad Politecnico de Madrid and examined theses at the Julius Kruttschnitt Mineral Research Centre (JKMRC) at the Univ of Queensland.

The EU project Less Fines initiated a continuing cooperation with professor Peter Moser at Montanuniversität Leoben in Austria, which has led to project cooperation and the joint publishing of research results.

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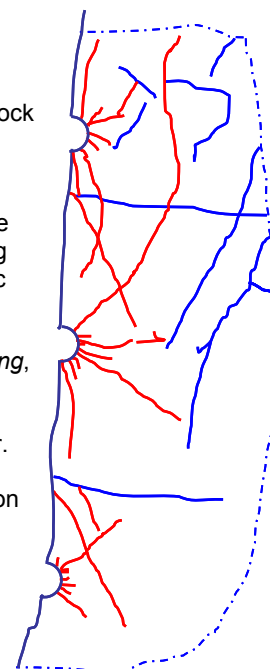
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