Members of the Commission on Mine Closure inspecting 100-year old underground mine workings in the North-East of France.

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With over 5000 members from 46 National Groups belonging to six regions, communication with and between members is a challenging task.

Fortunately the task has been simplified with the recent launch of the excellent ISRM website in April 2005 (pg 14). At its meeting in Sandton, South Africa, in September 2003, the ISRM Board approved the following motions regarding the use of information technologies:

“The main method of future communication between the ISRM and its members will be electronic, including development of an interactive website; distribution of the News Journal and the availability of abstracts of all ISRM sponsored conferences, commission and interest group reports. The Secretariat is instructed to find an appropriate IT service provider within easy access, but preferably within Lisbon, Portugal, for the creation and maintenance of the new ISRM website.”

The Board formulated the following specific objectives for the website:

- To promote the ISRM by making available to the technical community, through a new website, detailed information on the activity of ISRM, with the aim to be useful to rock mechanics practitioners and researchers, to increase the interest in rock mechanics and to attract new individual and corporate members to the ISRM.
- To serve the ISRM members by making available to ISRM members, through a password protected area of the ISRM website, specific information, which should justify being a member, such as newsletters and other publications, directory of members and a virtual library.
- To support the ISRM activity by improving ISRM efficiency by using specific IT tools for communication between Board members, Secretariat, National Groups, Commissions and Interest Groups, so as to stimulate electronic communication and to allow a better allocation of resources.

We are still in the process of streamlining and integrating our current modes of communication with members. These include the News Journal, the Annual Review, the Newsletter and the website. Should you have any comments or suggestions on improvements with communications to members please forward these either to myself or the Secretariat.

The responsibility for the technical content of each issue of the Journal is allocated in sequence to a regional Vice-President. Dr.-Ing. Claus Erichsen, (ISRM Vice President Europe 2003 - 2007) has done a magnificent job in securing the fascinating papers presented in this issue and I would like to thank him for his kind assistance and efforts in this regard.
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2003 - 2007

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There are several reasons why professionals in our (and I guess most other) fields are much busier, doing what we have to do and having less time to do what we want. Easier communication and, let me say it, abuse of easy electronic access, are perhaps some of the reasons.

There is more knowledge available now and we have to use it. My own estimate is that there are in the region of 2,000 papers on the topic of rock mechanics and engineering published each year, of which perhaps a third would be available in a language that any particular individual can understand. If half of those are accessible on various publications and websites, it means that if we are to stay on top we have to each find the time to read 300 papers per year. This is almost one per day!

In most countries there is a shortage of engineers. There are some exceptions, but not many. Less people have to do more and spend more time reading to stay with developments. Does this sound like complaining? No. It is not intended to be a complaint. Imagine if we were battling with the problem of what to do to stay busy!

On the organisational front, things are also happening with your society. As you are fully aware by now, the website is up and running and it is being visited regularly. Maybe it could be used more often, especially now that the Suggested Methods are available for download free of charge. We have picked up some problems with individual members registrations on the website. More often than not the problems have been that the membership lists, as we received them from the National Groups in Lisbon, are incomplete. Members must please ensure that their details are correct with the National Groups and the National Groups must please ensure that changes are sent through to Lisbon, otherwise problems are bound to occur.

The other important issue is the Federation of International Geo-engineering Societies (FIGS). The current position is that the Boards of all three Sister Societies (ISRM, IAEG and ISSMGE) have approved in principle that we go ahead and at the moment, your three Presidents are in the process of arranging a draft of the statutes to be created. The three Boards have had insight into the first proposal. In our case, we had a special Board meeting in Lisbon for this very important discussion. Comments have gone back to the drafting committee, ably led by Professor Niek Rengers of the IAEG and assisted by the three Secretaries General. The next step has been that the three Presidents reviewed the next draft at a meeting in May 2006 in the Netherlands. The final proposal will be ready for Board scrutiny shortly.

FIGS will only be officially in existence after Council approval. When will this happen? We hope that by the time we have our next Council meeting in November 2006, it will be possible to approach our Council, but this is not entirely in our hands as the other two Councils must also approve before we can formally create FIGS. The ISSMGE will not have a Council meeting this year (they only meet every second year) so that FIGS cannot be officially created before 2007 at the earliest. This is a very lengthy process, but it is necessary before we create a new organisation and it is complicated by the fact that the three societies work on different time schedules. It is also a very complex issue, as each society has certain concerns that have to be addressed to everyone’s satisfaction.

The special Board meeting in Lisbon was a very special occasion. A meeting of the Geotechnical Society of Portugal, the SPG, was arranged to coincide with the Board meeting. At this event, the presentations were delivered by the Board members, each one highlighting his and her personal area of specialisation. This was the first time in the history of the ISRM that all the Board members made technical presentations at the same conference.

Looking back at the history of the News Journal, one sad fact becomes apparent: it is becoming more and more difficult for busy professionals to find time to produce issues. The time between issues is getting longer and longer. Perhaps the time has come to consider a new format for distribution of news. One alternative that has to be considered is to make more effective use of our website and to release news in the form of bulletins as and when things happen, rather than wait for the production of a News Journal. The technical content of this issue was coordinated by Dr-Ing Claus Erichsen, VP for Europe, in spite of a very hectic schedule. Thank you, Claus!
THE MÜLLER AWARD

The ISRM Board decided at its Pau meeting in September 1989, to institute an award to honour the memory of Prof. Leopold Müller, the founder and first President of the Society.

Prof. Müller, as the enthusiastic founder of the Society, took the initiative to aggregate to the Salzburger Group scientists from all over the world interested in the new-born branch of science, rock mechanics, with the purpose to bring together and to give unity not only to the scattered knowledge obtained by groups working more or less isolated on problems posed by rock masses, but even to knowledge contributed by those pursuing other aims but with interest in the field.

The award is made once every four years in recognition of distinguished contributions to the profession of rock mechanics and rock engineering and consists of a special Müller Lecture to be delivered at the ISRM International Congresses, a work of art typical of the culture of the country hosting the Congress and a silver medallion with a portrait of Leopold Müller.

Recipients of the Müller Award

1991 E. Hoek CANADA
1995 N. Cook USA
1999 H. Einstein USA
2003 C. Fairhurst USA

The following 5 nominations for the Müller Award 2007 were received at the ISRM Secretariat:

- Nominated by the National Group of Australia: Prof. Ted Brown
- Nominated by the National Group of the USA: Prof. Richard Goodman
- Nominated by the National Group of Canada: Prof. Peter Kaiser
- Nominated by the National Group of Japan: Prof. Shunsuke Sakurai
- Nominated by the National Group of Sweden: Prof. Ove Stephansson

Selection of the recipient will take place during the ISRM Council meeting in Singapore, on the 7th of November, 2006. The award shall be conferred during the 11th ISRM International Congress in Lisbon, Portugal, in July 2007, where the recipient will deliver the Müller Lecture. A brief resumé of each nomination is given below. More information can be obtained from the ISRM Website.

Prof. Ted Brown

Academic and Professional Qualifications
Bachelor of Engineering (Hons), University of Melbourne, 1960
Master of Engineering Science (Hons), University of Melbourne, 1964
Doctor of Philosophy, University of Queensland, 1969
Doctor of Science (Engineering), University of London, 1985

Honours and Awards
1984 Consolidated Gold Fields plc Gold Medallist, The Institution of Mining & Metallurgy
1985 Nineteenth Sir Julius Wernher Memorial Lecturer, The Institution of Mining & Metallurgy
1995 Fellow of the Queensland Institute of Medical Research
2001 Appointed a Companion in the General Division of the Order of Australia (AC), (the highest level in the national honours system), “for service to the engineering profession as a world expert in rock mechanics and to scholarship through promotion of the highest academic and professional standards”
2002 Awarded a Centenary Medal by the Commonwealth of Australia, “for service to Australian society in mining and civil engineering
2004 John Jaeger Memorial Award, Australian Geomechanics Society.

Career Summary
1960 - 1964: Engineer, Coal Production Branch, State Electricity Commission of Victoria
1964 - 1975: PhD student (1964-65), Lecturer (1965-68), Senior Lecturer (1969-72) and Associate Professor (1973-75), Department of Engineering, University College of Townsville and, from 1970, James Cook University of North...
1975 - 1987: Reader (1975-79) and Professor (1979-87) of Rock Mechanics, Department of Mineral Resources Engineering, Imperial College of Science and Technology, University of London

1983 - 1986: Dean, Royal School of Mines, Imperial College

1985 - 1987: Head, Department of Mineral Resources Engineering, Imperial College

1987 - 1990: Professor and Dean of Engineering, The University of Queensland

1990 - 2001: Deputy Vice-Chancellor and, from 1996, Senior Deputy Vice-Chancellor, The University of Queensland

2001 – date: Senior Consultant, Golder Associates Pty Ltd, Consulting Engineers, Research Consultant, Sustainable Minerals Institute and Julius Kruttschnitt Mineral Research Centre, University of Queensland, and company director.

Prof. Richard Goodman

Education

1955 Bachelor's Degree with Major in Geology: from Cornell University, Ithaca New York

1958 Master of Engineering Science with Majors in Civil Engineering and Economic Geology: from Cornell University, Ithaca New York

1964 PhD in Engineering Science with Major in Geological Engineering, from Department of Mineral Technology, University of California, Berkeley, California

Professional experience

Various pre-doctoral positions in industry as geological engineer.

1966 - 1994 Assistant Professor, Associate Professor, and finally Full Professor of Geological Engineering, University of California, Berkeley, Department of Mineral Technology from 1964-66; Department of Civil Engineering (Geotechnical Engineering)

1994 - date Emeritus Professor of Geological Engineering.


Prof. Peter Kaiser

Education

Ph.D. (Geotechnical Engineering) University of Alberta, Canada (1979)

Dipl. Ing. (Civil Engineering) Federal Technical University (ETH), Zürich, Switzerland (1972)

Highlights of Academic and Professional Experience

1987 Professor of Mining Engineering, Chair for Rock Engineering and Ground Control

1989 Director of Geomechanics Research Centre, Laurentian University, Sudbury

1997 President, MIRARCO - Mining Innovation, Rehabilitation and Applied Research Corp.

1988-2001 Adjunct Professor at Queen's University, Mining Engineering; University of Toronto, Civil Engineering; and University of Waterloo, Earth Sciences and Civil Engineering


1997 - 1998 and U.S. Department of Energy Consultant to: consulting engineers, mines and public agencies on geotechnical engineering problems including ground control and rock support, shaft design, tunnelling and underground excavations in soils and rocks, rockbursts, slope stability, dam design, and pipeline failures.

Current and recent consulting assignments include: Alpine Rail Tunnels – Switzerland (Loetschberg,
Prof. Shunsuke Sakurai
President, Construction Engineering Research Institute, Kobe, Japan
Professor Emeritus, Kobe University, Japan
Professor Emeritus, Hiroshima Institute of Technology, Japan

Academic and Professional Qualifications
1958 BDSCE, Kobe University, Japan
1960 MSCE, Kyoto University, Japan
1966 PH.D in Civil Engineering, Michigan State University, USA
1975 Dr of Engineering, Nagoya University, Japan

Career Summary
1960 - 1962: Civil Engineer, Transportation Bureau, Osaka Municipal Office, Japan
1962 - 1966: Research Assistant, Michigan State University, USA
1966 Associate Professor, Department of Civil Engineering, Kobe University, Japan
1973 Professor, Department of Civil Engineering, Kobe University, Japan
1978 - 1979 Guest Professor, ETH, Zurich, Switzerland
1984 Visiting Professor, The University of Queensland, Australia
1994 Visiting Professor, Technical University of Graz, Austria
1999 - 2003 President, Hiroshima Institute of Technology, Japan
2004 Visiting Professor, Hubei University, China
2005 Visiting Professor, Chonqing University, China

Prof. Ove Stephansson
Visiting professor.
Department of Geodynamics, GeoForschungs-Zentrum, Potsdam, Germany

Research Fields:

Current activity:
- Evaluation of rock stresses in hard rocks
- Image analysis of geological materials
- Thermo-hydro-mechanical modeling of rock masses for radioactive waste repositories

Obtained Degrees:
1965 Phil Candidate, Uppsala University
1967 Phil Licentiate in Mineralogy and petrology, University of Uppsala
1972 Phil Doctor in Structural geology, tectonics and rock mechanics, Uppsala University
1972 Docent in Mineralogy and petrology, Uppsala University

Academic work:
1963 - 1974 Research Assistant at Hans Ramberg Tectonic Laboratory, University of Uppsala
1974 - 1975 Research Fellow, Division of Mineral Physics, CSIRO, North Ryde, Australia
1974 - 1990 Professor in Rock Mechanics, Luleå University of Technology, Sweden
1978 Guest researcher, Carlton University, Ottawa, Canada
1991 Professor in Engineering Geology, Royal Institute of Technology (KTH), Stockholm
1992 Head of the Secretariat of the international DECOVALEX project at KTH
1993 - 1997 Head of Department of Civil and Environmental Engineering, KTH, Stockholm
1998 Guest professor, Department of Engineering Geology, Technical University of Berlin 2000-2001 Visiting scientist, GeoForschungsZentrum (GFZ), Potsdam, Germany
2003 Visiting professor, GeoForschungs-
Bronze Medal and cash prize has been awarded annually since 1982 by the ISRM to honour the memory of Past President Manuel Rocha and to recognize outstanding young researchers in the field of Rock Mechanics.

The award shall be for an outstanding doctoral thesis in rock mechanics or rock engineering. The thesis must have qualified the candidate for a doctorate or the equivalent. To be considered for the award, a candidate must be nominated within two years of the date of the official doctoral degree certificate.

The nomination should be submitted to the appropriate ISRM Regional Vice-President by registered letter, and may be presented by the nominee, the nominee’s National Group or some other person or organization acquainted with the nominee’s work. The nomination should include the following supporting information:

- A one page curriculum vitae (include the name, nationality, place and date of birth of the nominee; also position, address, telephone & fax numbers);
- A thesis summary in English, of about 5,000 words, detailed enough to convey the full impact of the thesis, and accompanied by selected tables and figures, with headings and captions also in English; one hard and one digital copy are required;
- One copy of the complete thesis and one copy of the doctoral degree certificate;
- A letter of copyright release, allowing the ISRM to make copies for review & selection purposes.

Nominations for the 2008 Medal must be received by 31 December 2006.

Supplementary details of the selection procedure, conferring of the award, etc., are provided in ISRM By-Law No. 7, found in the ISRM Website. National Groups and Corresponding Members will be officially reminded by the Secretariat as the deadline approaches, but are encouraged to consider possible nominees and to recommend names to the appropriate ISRM Regional Vice-President as early as possible.

Recipients of the Rocha Medal

1982 A.P. Cunha PORTUGAL Mathematical Modelling of Rock Tunnels
1983 S. Bandis GREECE Experimental Studies of Scale Effects on Shear Strength and Deformation of Rock Joints
1984 B. Amadei FRANCE The Influence of Rock Anisotropy on Measurement of Stresses in Situ
1985 P.M. Dight AUSTRALIA Improvements to the Stability of Rock Walls in Open Pit Mines
1986 W. Purter AUSTRIA Calculation Model for the Behaviour of a Deep-Lying Seam Roadway in a Solid (but cut by Bedding Planes) Surrounding Rock Mass, taking into Consideration the Failure Mechanisms of the Soft Layer Determined In-Situ on Models
1987 D. Elsworth UK Laminar and Turbulent Flow in Rock Fissures and Fissure Networks
1988 S. Gentier FRANCE Morphology and Hydromechanical Behaviour of a Natural Fracture in a Granite, under Normal Stress – Experimental and Theoretical Study
1989 B. Frohlich GERMANY Anisotropic Swelling Behaviour of Diagenetically Consolidated Claystones
1990 R.K. Brummer S. AFRICA Fracturing and Deformation at the Edges of Tabular Gold Mining

The memorial to Manuel Rocha at LNEC in Lisbon
Excavations and the Development of a Numerical Model describing such Phenomena

1991 T.H. Kleine AUSTRALIA A Mathematical Model of the Rock Breakage by Blasting

1992 A. Ghosh INDIA Fractal and Numerical Models of Explosive Rock Fragmentation

1993 O. Reyes W. PHILIPPINES Experimental Study and Analytical Modelling of Compressive Fracture in Brittle Materials

1994 S. Akutagawa JAPAN A Back Analysis Program System for Geomechanics Application

1995 C. Derek Martin CANADA The Strength of Massive Lac du Bonnet Granite around Underground Openings

1996 M. P. Board USA Numerical Examination of Mining-Induced Seismicity

1997 M. Brady GERMANY Determination of In-Situ Stress Magnitude and Orientation of 9 km Depth at the KTB Site

1998 F. MacGregor AUSTRALIA The Rippability of Rock

1999 A. Daehnke S. AFRICA Stress Wave and Fracture Propagation in Rock

2000 P. Cosenza FRANCE Coupled Effects between Mechanical Behaviour and Mass Transfer Phenomena in Rock Salt

2001 D. F. Malan S. AFRICA An Investigation into the Identification and Modelling of Time-Dependent Behaviour of Deep Level Excavations in Hard Rock

2002 M.S. Diederichs CANADA Instability of Hard Rockmasses: the Role of Tensile Damage and Relaxation

2003 L. M. Andersen S. AFRICA A Relative Moment Tensor Inversion Technique applied to Seismicity Induced by Mining

2004 G. Grasselli ITALY Shear Strength of Rock Joints based on the Quantified Surface Description

2005 M. Hildyard S. AFRICA Wave Interaction with Underground Openings in Fractured Rock

2006 D. Ask SWEDEN New Developments of the Integrated Stress Determination Method and Application to the ÄSPÖ Hard Rock Laboratory, Sweden

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News from the ‘Bored’

Luis Lamas and Nielen van der Merwe passing the time during a train journey in the Netherlands.
Wave Interaction with Underground Openings in Fractured Rock

Geophysical Research Consultant and Hon. Visiting Fellow,
Department of Earth and Ocean Sciences
The University of Liverpool
E-mail: m.hildyard@btinternet.com

This thesis aims to develop improved models of seismic wave propagation around underground openings by modelling the interaction of waves with the fractured rock surrounding these openings.

Its primary motivation comes from the needs of industries which have stability problems, such as deep-level mining which has a rockburst problem, or nuclear waste storage where extremely long-term stability is required. Deficiencies are identified in previous modelling.

Few attempts have been made to compare the simulated waves with observed seismic waves, and where this has been attempted, the correspondence of waveforms near the surface of an excavation has been poor.

The thesis applies models to observations from controlled experiments and demonstrates that wave propagation can be reliably and accurately modelled. In so doing it motivates its application to the larger problem.

A three-dimensional finite difference model is used to simulate wave behaviour. The thesis covers the theory of its staggered-grid scheme and the implementation of fractures and cavities.

A practical method is developed to calculate numerical dispersion. Applying this to a number of different codes, indicates that general-purpose codes can be up to two orders of magnitude less efficient at wave propagation problems, which severely limits the size of problem to which they can be applied. The scheme used is efficient but limited to orthogonal geometries.

Methods are investigated which allow generalisation of this scheme without loss of efficiency. A new grid scheme, which has the same order of accuracy and efficiency as the staggered grid, is proposed for future development.

Laboratory experiments, which passed seismic waves through multiple plates representing aligned fractures, are modelled numerically using multiple displacement discontinuities.

There is a striking correspondence between the simulated and observed waveforms and the effect of the fractures on wave-speed and attenuation. However, a significant discrepancy is evident in the numerical waveforms for wave propagation across fractures.

The model is modified to include the effects of a non-uniform stress state using stress dependent fracture stiffness. The wave-fracture modelling is extended to in situ fractures in rock at the surface of a deep tunnel, using data collected in an acoustic emission experiment at the URL Mine-by tunnel.

Waveforms from the velocity scans are compared against those from elastic models and various models of fracture, such as random assemblies of small open cracks and larger fractures with a fracture stiffness.

A generic method is also developed for calculating the frequency variation of wave-speed and amplitude for collections of cracks.

Results indicate that it is possible to account for the wave-speeds and amplitudes using models with fractures.

The models of fracture are then applied to the rockburst problem to investigate the effect of an excavation on the amplitude and the distribution of ground motion. This provides important insights into the causes of effects such as the apparent amplification observed by researchers in this field.
Name?
Mark William Hildyard

Born?
England, 30th June 1964

What made you interested in rock mechanics?
I was originally an electronics engineer in computer and software engineering. Dr John Napier convinced me that there were some interesting and challenging problems in rock mechanics, which were becoming more tractable through the growth in computers. It was largely through his work that I became interested in this area.

What is your specialty in rock mechanics?
Developing and applying models of seismic waves. I’ve primarily used these to research rockbursts in mines, although have also applied these models in diverse fields, such as acoustic emission studies in nuclear waste storage, interpretation of micro-fracturing from ultrasonic measurements, simulating ground motion in pile driving, and most recently in identifying cracks in wave-guides.

What is your favourite topic in rock mechanics?
Research areas which allow bridging between the fields of rock mechanics, rock physics and seismology.

What hobbies do you have?
 Mostly sport; used to play musical instruments … but not for years.
M

y thesis “New Developments of the Integrated Stress Determination Method and Application to the Äspö Hard Rock Laboratory, Sweden” [Ask, 2004] is made up of two parts, one is new development of the Integrated Stress Determination Method (ISDM) [Cornet, 1993b]; the other is analysis of existing stress measurements and application of the ISDM to data Äspö Hard Rock Laboratory (HRL), Sweden.

The new developments of the ISDM include incorporation of overcoring stress data from CSIR- and CSIRO-type of devices, and integration of these with data from hydraulic fracturing and hydraulic tests on pre-existing fractures (HTPF). It allows description of the regional stress field in the rock mass with up to 12 unknown stress parameters. Furthermore, it may also be used to constrain elastic parameters when hydraulic fracturing/HTPF data are combined with overcoring data; then 14 parameters are included in the stress model.

A wealth of stress measurements have been made in the Äspö HRL by the Swedish Nuclear Fuel and Waste Management Co. (SKB). Despite the large number of data, the stress field is not well constrained. Not only does the result vary depending on measuring technique e.g. overcoring data indicated larger stress magnitudes compared to hydraulic fracturing data; but the results indicate non-linear stress magnitudes and orientations versus depth (i.e. a result discontinuities in the rock mass).

To evaluate the observed differences between existing hydraulic and overcoring stress data, a detailed re-interpretation was conducted.

Several measurement-related uncertainties were identified, and as a result, a rational for reducing these uncertainties was also developed which effectively reduced the discrepancies between the hydraulic and overcoring measuring results.

Modeling studies [Berglund et al. 2003] have shown that the redistribution of stresses at Äspö HRL to a large extent can be correlated to a major discontinuity, the NE-2 Fracture Zone, which divides the rock stress data into two stress domains, the NW and SE domains, respectively.

The effect of this zone was confirmed by my thesis, which suggests that the orientation of the maximal principal stress, $\sigma_1$, is equal to $124^\circ\pm13^\circ$ for the NW domain and $139^\circ\pm18^\circ$ for the SE domain. The application of the ISDM further verified the influence of the NE-2 Fracture Zone on the regional stress field. In the vicinity of the zone, the results indicate that the orientation of $s_1$ is perpendicular to the strike of the NE-2 Fracture Zone; and that the intermediate and minimal principal stresses ($\sigma_2$ and $\sigma_3$, respectively) are oriented parallel to the strike and the dip direction, respectively. The principal stress magnitudes appear less influenced by the zone. Limited amount of data exist outside the zone of influence from the NE-2 Fracture Zone; hence, the regional stress tensor is difficult to define. Most likely, the orientation of the regional $\sigma_1$ orientation is about $140^\circ$.
Biography

Name?
Lennart Daniel Ask (I took my wife’s name when I married her in the year 2000, my former family name was Ekman)

Born?
10th of April 1973

What made you interested in rock mechanics?
My father’s work (Lennart Ekman) and my Master Thesis guided by Prof. Ove Stephansson (KTH) and Dr. Jonny Rutqvist (LBNL)

Rock stress and its measurement

What is your specialty in rock mechanics?
Rock stress and its measurement

What is your favourite topic in rock mechanics?
Distribution of stresses in rock masses

What hobbies do you have?
My two kids, fishing, and fixing various things on my house

How do you spend your free time?
With my family

Do you play sport?
I play soccer and like to cross country ski

Do you watch any sport?
Preferably athletes (was active in my younger years (sprints between 60 and 400 m)

What is your favourite music?
Everything produced before 1995.

What is your favourite food?
For me, it is much easier to define what I do not like. However, sushi is certainly one favourite.

What non-technical books do your read?
Preferably books based on authentic historical events.

Are you married?
Yes, with Maria VS Ask

Do you have any relatives in rock mechanics?
My wife. To some extent, my father is also familiar with the field.

If you could have one wish come true, what would it be?
One more kid!

Please add anything interesting about yourself – eg. A defining moment in your life, a particular incident you remember, etc – not confined to rock mechanics!!

The event that I am about to tell certainly affected me for quite some time and it has made me much more careful in many aspects. The story takes place in central Sweden some eight years ago. I was on fishing holiday with one of my two older brothers, and his family. We had been trying to catch brown trout behind the hydropower plant of Stugun in the Indalsälven river. Due to poor result the first days, we decided to try fishing in the early morning. The following morning (about 05.00 am) proved to be very foggy and we reached the hydropower plant after about two hours. The normal traveling time is around one hour, but because of the fog, we had to stop several times to verify the flow direction of the river as we literally could not see anything. That way, we could at least determine that we were traveling upstream towards the hydropower plant. When approaching the plant, the current became increasingly stronger and we aimed at stopping 100 m downstream of the plant (you are not allowed to fish closer than 100 m from the plant). Due to the fog, we could not detect the plant until we were about 30 m from the concrete building. Happy to have finally reached the plant, we followed the current downstream some 70 m and released the anchor. After some fruitless fishing for about 30 minutes, we heard a very distant sound that was repeated a few times. We were puzzled by what this could be at this time of the day, but convinced ourselves that it was probably a truck horn. Then suddenly, a non-forgettable sound of surging water appeared and a wave of about 1 m high approached us in great speed. The wave hit the boat with great force and we were barely able to remain in the boat. The very strong current made our anchored boat jump like crazy from one side to the other while we desperately tried to release the anchor. After considerable time, we managed to release it and escaped to the shoreline downstream where the current was more manageable. Once the most obvious feelings of this close-to-death encounter started to fade away (I will not describe these in detail), we started to realize the stupidity of our actions. The distant sound we heard was nothing but the warning signal from the plant entailing that the water outlet from the dam gates were about to be increased. However, due to the fog, the warning sound appeared to origin from far, far away; hence, we ignored them. So, to those of you planning to fish behind hydropower plants, do not: (1) ignore warning signals; (2) anchor close to the plant; and (3) fish from a boat during zero-visibility conditions.
With the launch of the new ISRM website, the rock mechanics practitioners now have a tool where they can find all sorts of information about the Society, its organisation and history, conferences and meetings, commissions and interest groups, awards, corporate members, suggested methods and other publications. In a Members Area, ISRM members will find materials of their interest, such as the News Journal and a virtual library, or may wish to participate in discussion forums. Board members will have access to working areas and new services that will facilitate their routine work.

It is hoped that this new system will be positively received by the rock mechanics community. Launching of the system will be followed by continuous improvements that will prove necessary. Feedback from the users is essential, so that the system may become a useful working tool for all those involved in rock mechanics or in the activities of the ISRM.

In the future it is planned that Commissions and Interest Groups will be able to run micro-sites inside the ISRM system. A virtual library is being set up and will include abstracts and papers from the ISRM Congresses and other sponsored conferences.

Take full advantage of your ISRM membership to access the wealth of information available on the new ISRM website. Registration is easy:

• Open the website (www.isrm.net).
• Click on ‘Login’.
• Click on ‘you can register here’.
• Complete the membership information requested and click on ‘submit’.
• The Secretariat will then verify that you are a member of the ISRM.
• You will then receive a confirmation that you can login using your chosen Username and Password.

The reason for the registration process is that we need to make sure that only paying members have access to the Members Area. Remember that the ISRM has very few "private" (called "corresponding") members. The structure is such that the National Groups are the members.

We have also had problems with registrations, in cases where either the National Groups did not supply correct information to the ISRM or, more often, where members do not supply their updated contact details to the National Groups.

The administration can only be done at national level, as it would be impossible for the ISRM to directly maintain the records of over 5 000 members all over the world. We have to rely on the National Groups to supply the correct information and they in turn can only do it if you supply the correct information to the national secretariats! (see the form on page 15 to update your membership details with your National Group).

Once you are registered and you have access to the Members Area you will be able to:

• Download publications such as Suggested Methods and Reports.
• Participate in discussion forums.
• Access the virtual library which includes abstracts and papers from the ISRM Congresses and other sponsored conferences (under construction).

In addition to the Members Area the website, launched in April 2005, has three other areas:

• A public area containing information on the ISRM and its activities, a conference directory, a directory of corporate members and other items of interest.
• A password protected National Groups Working Area containing information relevant to the National Groups, such as Council papers, which can be downloaded.
• A password protected Board Working Area allowing Board members to exchange information in an efficient way.

Visit the website now. You don’t need to register to visit many parts of the site.

www.isrm.net
Change of contact details: Please send to your National Group, not the ISRM Secretariat

Title: ____________________________________________
Name: __________________________________________
Company: ________________________________________
Designation: ______________________________________
Telephone: __________________ Fax: __________________
E-mail: __________________________________________
Address: _________________________________________

National Group: ____________________________________

The Müller Award
The Rocha Medal

ISRM Information
News
Newsletter
News Journal

Products and Publications
Educational Software
Slide Collection
Suggested Methods and Reports
Videos

Links of Interest
IAEG – International Association for Engineering
Geology and the Environment
ICOLD – International Commission on Large Dams
IGS – International Geosynthetics Society
ISSMGE – International Society of Soil Mechanics
and Geotechnical Engineering
ITA – International Tunnelling Association
IUGS – International Union of Geological Sciences
SPE – Society of Petroleum Engineers

Discussion Forums

List of Corporate Members

ISRM Virtual Library
ISRM Board Meeting, Brno, May 2005

The ISRM Board met at the Congress Centre in Brno CZECH REPUBLIC, on 2005 May 16. The meeting took place in conjunction with the ISRM International Symposium on “Impact of the Human Activity on the Geological Environment” (EUROCK 2005). The meeting was chaired by the President of the ISRM, Prof. Nielen van der Merwe, and was attended by all the Vice Presidents of the respective geographical areas and by the two Vice Presidents at Large.

Matters such as finances, budget for 2006, ISRM website, co-operation with sister societies, progress in the organisation of the 11th Congress to be held in Portugal in 2007, applications for the 12th International Congress, selection of Symposia to be endorsed by the ISRM, activity of ISRM Commissions and of the Interest Groups, ISRM News Journal, as well as other matters of interest to the Society, were dealt with.

ISRM Board Meeting, Lisbon, January 2006

The ISRM Board met at the headquarters of ISRM in Lisbon, at the National Laboratory for Civil Engineering (LNEC), on 2006 January 20. The meeting was chaired by the ISRM President, Prof. Nielen van der Merwe, was attended by the President-elect, Prof. John Hudson, and by all the Vice Presidents, with the exception of Vice President at Large Prof. Qian Qihu, whose absence was due to health problems.

After reporting on the activities carried out since the Brno meeting, the Board considered the different items to be discussed and decided by the Council in Singapore in November 2006, such as finances, budget for 2007, 11th Congress of the Society, activity of ISRM Commissions and Interest Groups, News Journal, development of the Website, and other matters of interest for the Society.

Special attention was given to the co-operation with the Sister Societies (IAEG and ISSMGE), (see Message from the President) with regard to the creation of the Federation of International Geo-engineering Societies (FIGS). The President reported the outcome of the meetings with the Presidents and Secretaries General of the three Societies held in Ghent and Paris, which resulted in the drafting of the respective statutes. The Board studied them very carefully to ensure that they will correspond to the objectives envisaged for FIGS. The final version will be submitted for approval at the next ISRM Council meeting to be held this November in Singapore.

ISRM Council Meeting 2005

The International Society for Rock Mechanics held its Council meeting in Brno CZECH REPUBLIC, in conjunction with EUROCK 2005, organised by the ISRM Czech National Group. At the Council meeting 39 of the 42 National Groups were represented. Information was given and decisions were taken, as shown below:

Reports of the Regional Vice-Presidents
Each Vice-President presented a report on the activities carried out in the respective geographical area. These reports are reproduced under the section Regional Reports.

Accounts of 2004 and Budget for 2006
The ISRM accounts of 2004 and the Budget for 2006 were unanimously approved.

Development of the New ISRM Website
Information that the new Website of the ISRM had been launched on the 1st April 2005, was followed by the Secretary General's display of its navigation menu focusing in particular the following main features of its system:

- The public area contains information on the ISRM and its activities, a conference directory, a directory of corporate members and other items of interest;
- A password protected Members Area contains services provided only to ISRM members, such as discussion forums and publications to download;
- A password protected National Groups Working Area contains information relevant to
the National Groups, such as Council papers, which can be downloaded;

- A password protected Board Working Area allows Board members to exchange information in an efficient way;

- Commissions and Interest Groups will soon be able to run micro-sites, which are now being finalised, inside the ISRM system;

- A virtual library is being set up and will include abstracts and papers from the ISRM Congresses and other sponsored conferences.

**ISRM Sponsored meetings**

The following conferences sponsored by the ISRM were presented:

- **2006 May 09-12, Liege BELGIUM**
  Symposium on Multiphysics Coupling and Long Term Behaviour in Rock Mechanics (EUROCK 2006)

- **2006 June 19-21, Trondheim NORWAY**
  Symposium on In-situ Rock Stress

- **2006 November 8-10, Singapore**
• 2007 July, Lisbon, Portugal

Reports were presented by the organizers of EUROCK 2006, the 2006 International Symposium and the 2007 Congress.

**Commissions**

The following ISRM Commissions met in Brno on the morning of May 17. The respective reports are reproduced under the section Commission Reports:

– Case Histories
– Education
– Environment
– Maintenance and Repair of Underground Structures in Rock Masses
– Mine Closure

**Interest Groups**

A proposal from the Chinese National Group to establish an Interest Group on Underground Waste Disposal, to be chaired by Dr Ju Wang, was approved by the Board. Another Interest Group on Mining is already active.

**Co-operation with Sister Societies**

A report was presented by the ISRM President on the development regarding the eventual creation by the three Sister Societies (IAEG, ISRM and ISSMGE) of a Federation of International Geo-Engineering Societies (FIGS).

The Task Force appointed, with three representatives of each society, had revised the previous report and investigated the financial implications of the creation of FIGS. Following the meeting that took place in February 2005 in Ghent, Belgium, with the three Presidents and Secretaries General, a document had been prepared by the three Presidents for submission to the Councils of the three Sister Societies at their meetings in 2005.

The ISRM Council approved in principle the formation of FIGS and mandated the President to continue these discussions with the other two Societies, regarding concerns relating to the changes to the Statutes and By-laws required for the formation of FIGS. After obtaining the respective approvals, the Councils of the Sister Societies will be asked to formally approve the establishment of the Federation of International Geo-engineering Societies at their meetings in 2006 and 2007.

**Election of the ISRM President for the term 2007-2011**

As already announced in the previous issue of the News Journal, from the three nominations received, Professor John Hudson was elected by secret ballot as ISRM President for the term 2007-2011.

**Election of the Hosting Country of the 12th ISRM International Congress**

The applicants to host the 12th ISRM International Congress, in 2011, NG China and NG Singapore, in Beijing, and NG Korea, in Seoul, added more information to the one already presented in Kyoto, and finally the decision on the venue of the Congress was taken by secret ballot. The majority of the Council members voted in favour of the proposal presented by China and Singapore, and the 12th ISRM International Congress will be thus held in Beijing CHINA.

**Confirmation of the Venue for the Board, Council and Commission Meetings in 2006**

The date of November 2006 was confirmed for the next annual ISRM meeting, to be held in conjunction with the 4th ARMS, which will take place from 8 to 11 November in Singapore. The following annual ISRM meeting will take place in November 2007 and other meetings will be scheduled and confirmed as required and convenient.
ISRM Activity Report for AFRICA May 2005

Dr. Martin Pretorius
ISRM Vice President for Africa

1. Communication / Networking
   Communication that was initiated was unfortunately unsuccessful due to a lack in response from Ghana and Zambia. Very little progress has therefore been made on this due to the low number of practising engineers, poor communication and travelling distances between the different countries.

2. SANIRE
   The South African National Institute for Rock Engineering – SANIRE is quite active and the following summarise the activities:
   - There is a steady increase in the membership numbers. This is mainly due to a drive to recruit members that was launched during the latter half of 2004.
   - Professional registration for Rock Engineers at ECSA (Engineering Council of South Africa) is still in progress under the leadership of Professor Matthew Handley.
   - The Rock Engineering Competency Certification and Examination Committee that is a sub committee of the SANIRE is very active in bringing this certification under the auspices of the SANIRE. This is currently a Chamber of Mines of South Africa qualification and is administered by Technicon SA. It was suggested that the name of the certificate not be changed and to remain a Chamber of Mines Certificate.
   - Members of the SANIRE are still actively involved in the Mine’s Qualification Authority MQA where so-called unit standards related to rock engineering qualifications are developed by this group.
   - The South African National Institute of Rock Engineering (SANIRE), in collaboration with The South African Institute of Mining and Metallurgy (SAIMM), are proud to be hosting the 3rd Southern African Rock Engineering Symposium (SARES2005) in Randburg, Johannesburg between 10 and 12th October 2005. The theme of the Symposium is “Best Practices in Rock Engineering”. Approximately thirty papers will be presented over two days followed by one day of technical visits. A welcome cocktail party and a gala dinner will feature in the program.
   - A new Council for the SANIRE is currently being elected by members of the institute. Professor Matthew Handley, the Vice President, will take over the Presidency for the SANIRE from Dr. Francois Malan. The newly elected Council will officially take office at the Annual General Meeting that will take place during October 2005. Seventeen members have been nominated for Council of which six will be elected.

3. Rocha Medal Nomination
   Dr. Fernando M.C. Da Cruz Vieira was nominated by South Africa for the prestigious Rocha Medal Award. Dr. Fernando is currently practising as a Consulting Rock Engineer for AngloGold Ashanti in Brazil. Professor Budavari of the Mining Engineering Department nominated his thesis at the University of the Witwatersrand, Johannesburg, South Africa.
At present, the Asian region has 10 national groups (China, India, Iran, Japan, Korea, Nepal, Singapore, SE Asia, and Vietnam). In year 2004-2005, there is continuing increase of ISRM memberships in the region. ISRM National Groups of China, Japan and Korea remain to be the most active groups in Asia and contribute significantly in terms of membership and activities. Beijing or Seoul will be the venue of ISRM 2011 Congress and China (jointly with Singapore) and Korea have been actively preparing and proving to the ISRM that both are good candidate for hosting the Congress. China has a ISRM membership of over 400. Japan has almost 50 ISRM Corporate Members which makes half of the total ISRM Corporate Members. Asian National Groups also host 4 Commissions, 2 by Japan and 2 by China. Singapore remains a small yet active group and is organizing the 4th Asian Rock Mechanics Symposium. The organization has been well in progress and the symposium is expected to be a success one. The 4th ARMS will also be an ISRM international symposium and Singapore will be hosting the ISRM Council Meeting in 2006.

Iran is increasingly active and has applied to host the 5th Asian Rock Mechanics Symposium in Tehran in 2008. India, Israel, Nepal and Southeast Asia National Groups maintain their national activities and membership. Vietnam has not been paying its ISRM membership subscription since 2001. The Vice President for Asia has been trying to contact the National Group.

The Vice President for Asia is also studying the possibility of establishing ISRM National Groups in other part of Asia, including Indonesia, the Philippines, west and middle Asia.

In the interim since my last report in December 2004, there have not been many activities due to the summer break.

Membership
ISRM membership has increased in both branches. The AGS has 290 members and the NZGS have 73. It is encouraging to see student membership has also increased.

Both NGs are very active at Branch level with regular meetings and reporting on working groups.

Rocha Award Nominations
Three theses have been nominated for the 2006 award.

Conferences
The NZGS is putting together a bid for the 11th IAEG Congress in 2010 in Auckland under the title “Geologically Active”. Objectives are to celebrate the interrelationships between geology and engineering, similar to the successful GeoEng 2000 in Melbourne.

The AGS are organising the next 10th Conference on Geomechanics which is to be held in Brisbane 2007.

The 12th Australian Tunnelling Conference was recently held in Brisbane. Although this event is not sponsored by the AGS it had 300 delegates, which shows strong support for the industry.
ISRM Activity Report for EUROPE October 2004 - May 2005

1. ISRM-European Members

In May 2005 the European region had 23 National Groups (NG) and 2648 members, which amounts to 50 and 54 % of ISRM National Groups and ISRM-members respectively.

<table>
<thead>
<tr>
<th>European NG</th>
<th>Members</th>
<th>European NG</th>
<th>Members</th>
</tr>
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<tbody>
<tr>
<td>Austria</td>
<td>202/240</td>
<td>Netherlands</td>
<td>26/26</td>
</tr>
<tr>
<td>Belgium</td>
<td>48/48</td>
<td>Norway</td>
<td>230/230</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>2*/2*</td>
<td>Poland</td>
<td>42/56</td>
</tr>
<tr>
<td>Croatia</td>
<td>56/56</td>
<td>Portugal</td>
<td>158/158</td>
</tr>
<tr>
<td>Czech Rep</td>
<td>23/23</td>
<td>Russia</td>
<td>35/35</td>
</tr>
<tr>
<td>Denmark</td>
<td>3/3</td>
<td>Slovakia</td>
<td>20/20</td>
</tr>
<tr>
<td>Finland</td>
<td>67/64</td>
<td>Slovenia</td>
<td>26/26</td>
</tr>
<tr>
<td>France</td>
<td>173/173</td>
<td>Spain</td>
<td>145/145</td>
</tr>
<tr>
<td>Germany</td>
<td>337/329</td>
<td>Sweden</td>
<td>130/130</td>
</tr>
<tr>
<td>Greece</td>
<td>99/99</td>
<td>Switzerland</td>
<td>167/167</td>
</tr>
<tr>
<td>Iceland</td>
<td>7/7</td>
<td>Turkey</td>
<td>70/75</td>
</tr>
<tr>
<td>Ireland</td>
<td>3*/3*</td>
<td>UK</td>
<td>315/331</td>
</tr>
<tr>
<td>Italy</td>
<td>223/207</td>
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</tr>
</tbody>
</table>

Σ: 23
Σ: 2648 + 5*)

(*) Corresponding Members

Information about the secretariats, presidents and secretaries are available on www.isrm.net.

Discussions have been carried out to create additional National Groups and to increase the number of members.

2. ISRM-Symposia

The EUROCK 2004-Symposium was carried out in Salzburg, Austria in October 2004 and 152 papers were published in the proceedings. Available at www.vge.de.

An ISRM-Regional Symposium "Underground Space and Rock Mechanics" took place in Moscow, Russia in January 2005. More than 50 papers are published in the proceedings.


The Belgian Group got approval to organize the EUROCK 2006 Conference in Liege in May 2006. The topic will be "Multiphysics Coupling and Long Term Behaviour". This conference will also be an ISRM-sponsored-Regional Symposium.

Information is available in the net: www.eurock06.org. Deadline for submission of abstracts: September 1, 2005.

In situ Rock Stresses was the topic of another ISRM-sponsored Regional Symposium held in Trondheim, Norway in June 2006. Information is available in the net: www.rockstress.org.
Deadline for submission of abstracts: July 31, 2005.

3. ISRM-News Journal

The issue 1/2006 will be illustrated by European ISRM NG’s.

4. European Council Meeting

Dr. Erichsen has initiated, that the European National Groups meet once a year. The meetings are called European Council Meetings (ECM). We have had two meetings until today, one in 2004 in Kyoto, Japan and one in BRNO, Czech Republic in 2005. ECM’s in the future shall take place at every International ISRM-Symposium and Congress. It is the aim, to promote the exchange of information on rock mechanics and rock engineering within the European Countries and the ISRM.

5. EUROCK Symposia

The following EUROCK-Conferences have been held since 1992 and will be carried out respectively:

- 1992 UK, Chester
- 1993 Portugal, Lisbon
- 1994 Netherlands, Delft
- 1996 Italy, Turin
- 1997 Austria, Vienna
- 1998 Norway, Trondheim
- 2000 Germany, Aachen
- 2001 Finland, Espoo
- 2002 Portugal, Madeira
- 2004 Austria, Salzburg
- 2005 Czech Rep., Brno
- 2006 Belgium, Liege

For the year 2008 applications are welcome.

6. FIGS - Federation of International Geoengineering Societies

Dr. Erichsen has the honour to be a member of the FIGS – Joint Task Force and participated in the elaboration of a proposal to develop a forum or federation. This proposal was sent to the Presidents of the three sister societies IAEG, ISRM, ISSMGE. The 3 Presidents modified this proposal and made it available to the ISRM-Council in BRNO, May 2005.

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ISRM Activity Report for North America

CANADA (input from Professor John Hadjigeorgiou, CARMA President)

**Background**

In Canada, the ISRM National Group is the Canadian Rock Mechanics Association (CARMA). Membership to CARMA is through either the Rock Mechanics Committee the Canadian Institute of Mining and Metallurgy (CIM) or the Rock Mechanics Division of the Canadian Geotechnical Society (CGS).

**Current Situation**

Membership to the Canadian Geotechnical Society includes in its fee structure for the automatic adhesion to an international society of their choice. In 2003, 50 people identified CARMA and by consequence the ISRM as the society of choice, and another 60 identified Rock Mechanics as a second division choice (without membership to CARMA & the ISRM). Members of the Canadian Institute of Mining indicate the field of interest that can be (Metal Mining, Mineral Economics Society, Maintenance Engineering, Rock Mechanics etc.). Currently only
Rock Mechanics members of the CIM have an option to join an international society. This costs an additional 30$Cnd for CARMA and ISRM Membership (including the ISRM Quarterly News Journal). In 2003, 598 people indicated rock mechanics as their area of interest and are members of the rock mechanics committee. A further 115 paid the additional fees for membership to CARMA and by consequence to the ISRM. The ISRM membership from Canada currently stands at 165.

The last few years have seen a big dissatisfaction of members of the CIM Rock Mechanics Community with the ISRM. This escalated to the point where the Canadian Institute of Mining questioned the practice of facilitating adhesion to the ISRM. All complaints were related to the ISRM Journal: irregular dates of publication, wrong addresses. The CIM Rock Mechanics Committee refunded members who should have, but did not receive the Journal. Currently, there is a degree of dissatisfaction on the part of both CIM and CGS members over the last paper issue of the Journal (lack of technical content). The same complaints begin to resurface about the Journal not being available on a regular basis. Further complaints have focused on the ISRM web page. If the ISRM Journal is to be available to all surfers over the web, what do paying members gain with adhesion? Unless these issues are resolved in the immediate future the number of Canadians that also are ISRM members is expected to further decline.

**CARMA Activities**

In 2004 CARMA cooperated with the American Rock Mechanics Association (ARMA) in the organization of the North American Rock Mechanics Symposium in Houston. CARMA members have also contributed in the development of Rock Mechanics Sessions during the Canadian Institute of Mining & Metallurgy, Annual General Meeting in Edmonton (May 2004) and the Canadian Geotechnical Conference in Quebec City (October 2004).

**Mexico**

Over the past two years, numerous attempts have been made by the V-P North America (VPNA) and the ARMA staff to establish contact with a person speaking for Mexico with regard to ISRM. These attempts did not establish a viable correspondent. Mexico, a country of 105 million people has 5 members in ISRM.

In August 2004, the VPNA wrote a message to Mr. Carlos Garcia, President of the Mexican Society for Rock Mechanics, highlighting the fact that Mexico was long overdue in its ISRM dues and informing him of the options that the ISRM Board was offering to such countries to remedy their situation. He was also informed that, in case of further delinquency, Mexico could be expelled from ISRM. Although the receipt of that message was acknowledged, to this day there has been no other response to these communications. This does not bode well for the future of Mexico within ISRM.

**United States**

ARMA is the National Group for the U. S. The VPNA is also the current President of ARMA. The U.S. now has 407 ISRM members, a significant increase from the previous year.

ARMA organized a North American Rock Mechanics Symposium (NARMS) in Houston, Texas, in June 2004. This NARMS was supposed to be organized in and by Mexico. When Mexico defaulted, the U.S. stepped in. Mexico having also declined to hold the next NARMS, in 2006, the Board of ARMA terminated the 3-country (Canada, Mexico, U.S.) NARMS agreement. It then established a new joint Symposium process with Canada (CARMA), 2 years in the U.S. and 1 year in Canada over each 3-year cycle.

The 2005 US/Canada Rock Mechanics Symposium will be held in June 2005, in Anchorage, Alaska. The 2006 US/Canada Rock Mechanics Symposium will be held in Golden, Colorado. This will be the 50th/golden anniversary of the 1st U.S. Rock Mechanics Symposium that was held in Golden in 1956. The 2007 Canada/US Rock Mechanics Symposium will be held in Canada.
ISRM Activity Report for South America  May 2005

1. Introduction
Rock Mechanics development in the continent is mainly associated to mining engineering, civil engineering (dam and tunnelling) and petroleum engineering. In general, the ISRM National Groups started its activities under the umbrella of the soil-mechanics societies already existing in the beginning of the years 70. This format is still applied up to now.

Unfortunately in these last 15 years, the influence of ISRM in the region was slowly decreasing mainly in these last years. Some National Groups have left the Society without others coming to joint the Society, despite the efforts of many colleagues.

Certainly the economic restraints and political changes in the region, has caused a dramatic worsening of the situation in the continent, having as a consequence the fact that in the beginning of the XXI Century the number of the National Groups in the continent is reduced to 5 NGs compared to the 8 NGs existing in the beginning of the 90’s. Number of members were also reduced in all the 5 remain NGs.

In view of that, the Vice-President has focused strong efforts to motivate the existing National Groups to participate actively in the rock mechanics activities in the continent and abroad and to improve communication among the NGs in the continent. This goal was comproved by the number of proxies to represent South America in the last elections in Brno. There has been also an effort to make the presence of the Society to be stronger in the continent; getting new memberships and corporate members to be associated for ISRM. Among others activities the Vice-President one very important for the rock mechanics community in the continent will be the organization of the VI South American Congress, to be held in 2006 in Colombia.

Those elections were an important recent mark for our continent.

There was a strong effort from the Vice-President to get the proxies such that all the five countries could be represented in the Council Meeting. South America had an unanimous position in the voting for the election of the new President of ISRM as well as in the choice for the country that would host the 12th ISRM Congress in 2011. The Vice-President represented three countries – Argentine, Colombia, Paraguay – and the President of the Brazilian NG represented Venezuela and Brazil.

3. National Groups
The activities of the National Groups have been very active in these last two years, despite the economic restraints in the majority of the countries. There has been the organization of important events in 2004 in Paraguay and Argentine, already said in the last Report of the Vice-President. All the five countries were represented in the last Council Meeting in Brno (May, 2005), some by proxies. Communication has been improved in the Region in these last two years.

The President of the Brazilian-NG participated in the Council Meeting held in Brno (May, 2005). The Brazilian-NG has started the organization for the IV Brazilian Rock Mechanics Symposium to be held in association with the Brazilian Soil Mechanics and Geotechnical Engineering Conference to be held in August 2006, in the city of Curitiba, State of Parana, South of Brazil. The NG is also participating in the organization of the short course “ III Rock Engineering Course” to be held in October 2005, in the Institute for Technological Research of São Paulo (IPT).

The Colombia National Group started the organization for the VI South American Congress (6th SARMG) to be held in the city of Cartagena, in October, 2006.

This Congress will be organized together with the XI Colombian Geotechnical Congress.
1. The Korean Society for Rock Mechanics (KSRM) published “Numerical Analysis in Rock Engineering” on March 10, 2005. This is the first of Rock Engineering Series which KSRM began to promote from one year ago. All of the series will be written in Korean language targeting Korean engineers who have taken fundamental courses of rock mechanics in college. The first book consists of 14 chapters contributed by 14 authors and it covers many topics in numerical analysis such as FEM, DEM, BEM and DDA with applications to rock mechanics problems.

2. Dr. So-Keul Chung was elected as KSRM president at National Congress of KSRM on 31, March, 2005. After the former president Sang-Yeul Choi, Dr. Chung will take 2 years term of office until March 2007. He is currently a Principal Researcher of Korea Institute of Geoscience & Mineral Resources (KIGAM). According to the new election of the president, the Board members of KSRM were changed. The new Board of KSRM consists of a president, four vice-presidents and twenty-seven directors. Steering board members and Secretary General of KSRM are as follows.

**President:**
Dr. So-Keul Chung (skchung@kigam.re.kr)

**Vice-President:**
Dr. Kong Chang Han (hankc@kigam.re.kr)
Mr. Chu Hwa Kim (juhwa@dic.co.kr)
Dr. Doo Hwa Lee (shedhl@hotmail.com)
Prof. Hyung-Sik Yang (hysyang@chonnam.ac.kr)

**Secretary General:**
Prof. Jae-Joon Song (songjj@snu.ac.kr)

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**NG China** is working for more contribution to the development of ISRM

NG China and NG Singapore won the competition of hosting the 12th ISRM Congress, in BRNO in May this year. After that, NG China is planning to make more efforts to contribute to the development of ISRM. In November 2005, NG China and the CSRME celebrated its 20 years anniversary in Hangzhou, one of the most important topic of the council meeting is how to make more efforts in the international activities of ISRM.

Recent 2~3 years the number of the normal ISRM members in China is increased rapidly, almost 100 new members join in the NG China of ISRM each year. Among them most are young scholars and engineers working in the field of Rock Mechanics and Rock Engineering.

In addition, more and more Chinese participants attended the important ISRM sponsored International symposia, in 2003 (Johannesburg) more than 30, in 2004 (Kyoto) more than 40, and in 2005 (Brno) more than 50.

Prof. Shen Fengsheng was appointed as the President of the ISRM Commission on Case Histories in Rock Engineering, and Prof. Cai Meifeng was appointed as the President of the ISRM Commission on Education last year. More and more Chinese experts become the members of different Commissions and Interest Groups of ISRM.

Furthermore, NG China is planning to set up a new website in English to strengthen the connection and exchange with international colleagues late this year.
NG USA and NG Canada

The American Rock Mechanics Association (ARMA) held the 40th U.S. Rock Mechanics Symposium in Anchorage, Alaska, June 26-30, in cooperation with the Canadian Rock Mechanics Association (CARMA). The Symposium was organized by faculty members from the University of Alaska, Fairbanks, G. Chen, S. Huang, and W. Zhou, assisted by the Executive Director of ARMA, P. Smeallie. The conference was attended by 240 people from 40 countries, and 183 papers were given, including 4 keynote presentations. Four short courses were offered prior to the Symposium. All paper submissions and reviews were processed through the ARMA website, www.armarocks.org. Proceedings were distributed on a CD that is available from ARMA. Special events included an award ceremony where Professor Richard Goodman received the Outstanding Achievement Award from ARMA for his extensive contributions to our field. Others were recognized as well in the Rock Mechanics Research, Applied Rock Mechanics, and Ph.D. thesis categories for their theoretical and practical contributions. A dinner cruise held on Prince William Sound (photo) went late into the evening in high summer daylight.

The next U.S. Rock Mechanics Symposium was held in June from 17-21, 2006, in Golden, Colorado. It was planned as a special conference, marking the 50th anniversary of the first U. S. Symposium.

Symposia News

NG China and NG Singapore to host the 12th ISRM International Congress in 2011

The applicants to host the 12th ISRM International Congress, in 2011, NG China and NG Singapore, in Beijing, and NG Korea, in Seoul, added more information to the one already presented in Kyoto, and the final decision on the venue of the Congress was taken by secret ballot. The Council members voted in favour of the proposal presented by China and Singapore, and the 12th ISRM International Congress will be thus held in Beijing CHINA.

ISRM Sponsored meetings:

The 2005 ISRM International Symposium EUROCK 2005

Impact of the Human Activity on the Geological Environment

Brno, Czech Republic, 2005 May 18-20

The ISRM 2005 International Symposium EUROCK 2005 took place in Brno (Czech Republic) from 18 to 20 May. The venue of the symposium was Voronez I - modern congress centre and hotel. This hotel provided suitable accommodation for discussions in two parallel sessions for more than 200 symposium participants from 29 countries.

The main symposium theme "Impact of Human Activity on the Geological Environment" was divided into eight main topics dealing with laboratory and field research investigations in geomechanics, geoengineering and mathematical modelling. A.A. Balkema Publishers published the proceedings including 118 papers dealing with these topics.

Organisers of the symposium prepared three excursions and workshops for participants on Thursday - second day of the regular symposium. "Geotechnics" was discussed in University of Technology in Brno. Theme "Mineralogy and microstructures" was presented in Palacky University in Olomouc and "Laboratory measurements in geomechanics" in Institute of Geonics ASCR in Ostrava. The presentation of companies dealing with geomechanics was organised during the symposium, too. The social events for participants and accompanying persons completed the fulltime program.

Symposia News (continued)

• 2007 July 9-13, Lisbon, Portugal

• Submission of Abstracts for the 11th Congress of the ISRM to the National Groups
  Abstracts should be submitted to the ISRM National Groups. National Groups are to send those selected to the Congress Organizing Committee by 30 September 2006.

• VI South American Congress on Rock Mechanics: 3rd circular released
  The VI South American Congress on Rock Mechanics, an ISRM Regional Symposium, will take place in Cartagena, Colombia, October 8-13, 2006. The 3rd information circular was now issued.

• GoldenRocks 2006 - the 50th anniversary of the U.S. Rock Mechanics Symposium

• Int. Symp. on In-Situ Rock Stress: programme now available
  The International Symposium on In-Situ Rock Stress will take place in Trondheim, Norway, 19 to 21 June 2006. The preliminary programme is now available.

• EUROCK06 final bulletin now available
  The ISRM Regional Symposium EUROCK06 took place in Liege, Belgium, 9 to 12 May 2006. The final bulletin is now available.
ISRM Commission on Case Histories in Rock Engineering

1. Introduction

The Commission on Case Histories in Rock Engineering (CCHRE) is a newly established organization under ISRM. Its President is Dr. Fengsheng Shen from China Authority of Water Resources Planning and Consulting. At the infant period of 2004, CCHRE mainly carried out the following work:

1. Completing the membership. Members recommended by the Vice Presidents representing various continents have been appointed, while the North America position was still vacant.
2. Guidelines of CCHRE. The document of drafted CCHRE guidelines was circulated among the members.
3. The first meeting of CCHRE. It was held on November 29, 2004 at the International Conference Center of Kyoto, Japan. Dr. Fengsheng Shen, President of CCHRE. Dr. Zuyu Chen, Secretary General of CCHRE, presented a keynote lecture entitled 'The landslide and engineered slope inventory for China's water resources and hydropower development'. The participants discussed various issues concerning the establishment and activities of CCHRE.

2. Work progress in early 2005

During the first half of this year, CCHRE has carried out the following work.

1. On behalf of Chinese National Group of Rock Mechanics and ISRM CCHRE, the Yangtze River Academy of Sciences submitted the proposal of hosting 'International Regional Symposium on Geotechnical Exploration and Monitoring – Recent Advances and Case Studies' in 2007. The proposal was discussed in ISRM Annual Meeting. Due to the proposed date of the Symposium being too close to the ISRM Congress, the Symposium was reorganized at some other convenient time. New arrangements will be discussed in the next Section of this Report.
2. After a consultation with the Secretariat of ISRM, we contacted Prof. Shamsher Pakash from the University of Missouri-Rolla, Chairman of the Organizing Committee of the 6th International Conference on Case Histories and invited him as a member of CCHRE. He has accepted the invitation. Therefore the issue of vacant North America membership has been solved.

3. Current work being undertaken

CCHRE is currently working on the following activities:

1. It is planned to have a one-day Workshop on Real-time Monitoring on Geohazards before the 10th International Symposium on Landslides (ISL) to be held in Xi'an China from June 30 to July 4. We find that postponing the proposed Regional Conference to 2008 will create a problem of being too close the 10th ISL. We therefore propose a small-scale activity that focuses on a small but very popular subject – real time monitoring. The workshop also works as preparation of "International Regional Symposium on Geotechnical Exploration and Monitoring – Recent Advances and Case Studies" to be held some time in 2010.
2. A website of CCHRE shall be attached to the ISRM home page, which will be the main channel to allow CCHRE to communicate with and provide service to ISRM members.
3. We are seriously considering a CCHRE working group on ISRM suggested methods of documenting geohazards and rock engineering case histories in digital forms and a half-day workshop attached to the 2007 ISRM Congress.
4. To assist CCHRE's work, we are planning to establish a Chinese sub-commission called CSRME Commission on Case Histories in Rock Engineering. We have allocated Hongda Consulting Corporation as the
hosting organizer and necessary money to start the work.

(5) In his work report, Prof. Shen explained a plan of creating a postgraduate course entitled 'Case histories in geotechnical engineering', organized by the Tsinghua University, which will be open to all students in Beijing, China. This work will be carried out in collaboration with ISRM Commission on Rock Engineering Education, which is also hosted by CSRME. With this course, we will explore the feasibility of this educational method. This work will be put into action after CSRME Commission on Case Histories in Rock Engineering is established.

Fengsheng Shen
President of the Commission

ISRM Commission on Education

Since last December, the establishment of the membership of the Commission on Education has been the major task. With the help and recommendation from the Past President Dr. Marek Kwaniewski, ISRM National Groups and the former members, the candidates of the new commission membership were proposed and sent to the ISRM Secretary General for a formal approval by the ISRM President in March, 2005. At present, with the approval of the ISRM President, the membership of the Commission is composed by 20 members from 15 countries. There are two potential members to be extended from, Australia, and India.

This morning, the ISRM Commission on Education held a commission meeting. It is the first meeting since the new membership was established. Nine members attended the meeting. In the meeting, we discussed extensive topics and activities of the commission. In the near future, we will concentrate on the following tasks:

1. To re-establish a list of universities which offer the course of Rock Mechanics and a list of professors involved in rock mechanics around the world.

2. To hold an International Symposium on Education of Rock Mechanics and Global Doctoral Forum of Rock Mechanics and Engineering in 2007. In the commission meeting held in the morning, some participants suggested that it is better to combine this symposium with the 4th Asian Symposium on Rock Mechanics to be held in Singapore in 2006 or the 11th International Conference of Rock Mechanics to be held in Lisbon, Portugal in 2007.

3. To Organize a lecture tour in 2006 or in 2007. Following the successful experience and reflection from the 1st ISRM lecture tour 2001 in Beijing, Xuzhou and Chongqing, P. R. China, the ISRM Commission on Education is planning to organize the successive lecture tours. The date and target country of the 2nd ISRM lecture tour will be determined after further discussion within the Commission members.

4. To collect educational software, slides, video tapes and multi-media works.

5. To update the information on education issued on ISRM website. Following the excellent work done by past President of ISRM Commission on Education, a great amount of information including the data of universities and persons involved in education of rock mechanics, material (books, software, videotapes and slides), and teaching agenda etc. can be found through ISRM website. The content and information will be continuously collected and updated in order to catch up with the need of study and education on rock mechanics and engineering.

6. To collect the abstract of doctoral theses all around the world and issue them through the ISRM web.

The Commission on Education will make all its efforts to challenge the difficulties, realize the goal and take on the obligation in honour of ISRM.

Meifeng Cai
President of the Commission
ISRM Commission on Maintenance and Repair of Underground Structures in Rock Masses

1. Welcome
The President welcomed and introduced the participants:
- Prof. He Manchao (China)
- Dr Lúis Nolasco Lamas
- Prof. Manuel Romana
- Prof. Toshihiro Asakura

Other participants from China, Korea and Singapore assisted the meeting.

2. Agreement on the Agenda
The Agenda was accepted as proposed.

3. Presentation of case histories
Prof. Toshihiro Asakura presented several case studies regarding the following Japanese tunnels: Tsukayama (railway), Enasn (road), Iwamoto (tailrace), Oyamano (road), Fukuoka (railway) and Rebunhama (railway). A list of documents was given by Prof. Asakura. Dr Christian Choquet sent a very important document prepared by CETU (France), a guide for inspection of road tunnels.

4. Planning of the activities: different tasks
Taking into account the suggestions of the present members, the following distribution of activities was proposed:

**Task 1.** Collection of case histories. Dr Atsunori Tanimoto and Prof. Toshihiro Asakura (contribution of the Japanese Working Group on Tunnel Maintenance), Prof. Ribeiro e Sousa (case histories in Portugal – railway and road tunnels and underground hydroelectric schemes), Prof. Fulvio Tonon (case histories from USA and Italy), Ms Edna Frazillio (case histories from São Paulo Metro), Prof. Manuel Romana (case histories from Spain), Dr Christian Choquet (case histories from France), Dr Lee Peterson (case histories in USA), and Prof. He Manchao (case histories of in China).

**Task 2.** Deterioration of rock masses and linings. Dr Christian Choquet (catalogue describing anomalies affecting rock masses and linings), Dr Nolasco Lamas (deterioration of rock masses – main anomalies and their causes), Prof. Maneel Romana (deterioration phenomena) and Prof. Ribeiro e Sousa (modeling of masonry linings and grouting).

**Task 3.** Guidelines for inspection and safety control of underground structures. Dr Christian Choquet (guide for inspection of road tunnels), Prof. Toshihiro Asakura and Dr Atsunori Tanimoto (guide for inspection of railway tunnels), Prof. Fulvio Tonon (inspection and safety control of tunnels), Ms Edna Frazillio (experience on maintenance software for underground structures in subways and hydraulic works), Dr Nolasco Lamas (methodologies of inspection and safety control) and Prof. Ribeiro e Sousa (maintenance software for railway and hydraulic underground structures and guides for inspection of railway tunnels).

**Task 4.** Guidelines for repair of underground structures. Prof. Toshihiro Asakura and Dr Atsunori Tanimoto (Japanese experience of repairing of railway tunnels), Dr Christian Choquet (repair techniques in road tunnels), Ms Edna Frazillio (repair techniques for subway tunnels), Dr Lee Peterson (repair techniques used in USA for underground structures) and Prof. He Manchao (repair techniques used in China for underground structures).

**Task 5.** Final report to be published as an ISRM document. All the members will participate in the elaboration of the final report, with the coordination by Prof. Ribeiro e Sousa, Dr Christian Choquet and Prof. Toshihiro Asakura.

**Task 6.** Specialized Workshop at 2007 ISRM Congress. Prof. Ribeiro e Sousa (coordination of the Workshop during ISRM Congress), Prof. Manuel Romana (representing the ISRM NG Spain) and Prof. Toshihiro Asakura (representing the ISRM NG Japan).
5. **Specialized session at ISRM Congress, 2007**

It is planned to have a one-day specialized session during the 11th ISRM Congress, to be held on July 12, 2007. It was considered important to have the cooperation of ITA and AFTES. Apart from an active forum of discussion, the aim of the Workshop is to have the written contributions in a CD-Rom.

6. **Date and venue for next meeting**

The third meeting was appointed to Singapore, November 2006, during the 4th Asian Rock Mechanics Symposium.

L. Ribeiro e Sousa  
President of the Commission

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**ISRM Commission on Testing Methods**

Although the last Commission report was presented relatively recently (in November 2004 at Kyoto), I am pleased to report that there have been significant developments since then:

- Another ISRM Suggested Method is in press,
- The Fracture Toughness Suggested Method Group are hard at work, and
- Agreement has been reached with Elsevier that all the existing ISRM Suggested Methods can be re-published as a Special Double Issue of the International Journal of Rock Mechanics and Mining Sciences (IJRMMS).

1. The new Suggested Method is the “ISRM Suggested Method for determining the Shore Hardness value for rock” which was co-ordinated and written by R. Altindag and A. Güney of the Department of Mining Engineering, Engineering and Architecture Faculty, Süleyman Demirel University, 32260 Isparta, Turkey. This new ISRM Suggested Method is currently in press and will be published soon. It updates and replaces the hardness section of the 1978 “Suggested Methods for Determining Hardness and Abrasiveness of Rocks” document produced by the ISRM Commission on Standardization Laboratory and Field Results. Int J Rock Mech Min Sci Geomech. Abstr 1978; 15: 89-97.

2. I mentioned in my last report that on 24 September 2004, a Fracture Mechanics Workshop convened by Ove Stephansson, and which I attended, was held in Potsdam, Germany, to discuss the generation of a new suite of fracture toughness SMs. This is to update the 1988 SM co-ordinated by Finn Ochterlony and the 1995 SM co-ordinated by Bob Fowell (see the complete list of ISRM on the second page this report). The purpose of the Workshop was explicitly to formulate the group which will generate the new SMs and to consider how to develop supporting papers for a Special Issue on Fracture Toughness in the same style as the Rock Stress Estimation Special Issue. The Potsdam initiative was well received and is going ahead. Since, my November 2004 report, Dr Majid R. Ayatollahi, of the Department of Mechanical Engineering, Iran University of Science and Technology Narmak, Tehran, Iran has joined the Group. If anyone else is interested in contributing to the fracture toughness SMs, please contact Ove Stephansson.

3. An issue which has been unresolved for some time is whether to re-print a hard copy version of all the ISRM Suggested Methods. Earlier the book “Rock Characterization, Testing and Monitoring: ISRM Suggested Methods”, edited by E.T. Brown, was published which contained all the Suggested Methods – up to the 1981 date of publication of the book. Many will recall this yellow cover book which is now firmly out of print. Elsevier have now scanned in all copies of the International Journal of Rock Mechanics and Mining Sciences from 1964, so that all the ISRM SMs are currently available as pdfs from www.sciencedirect.com. I have also supplied the ISRM Secretariat with copies of these pdfs. However, many people have suggested to me that all the SMs should be re-published in book form so that they can be easily desk referenced with all the advantages of a book format. Elsevier have agreed that they can all be published as a Double Special Issue of the IJRMMS – copies of which will be sold individually, thus achieving the hard copy re-publication. This is a major development for the ISRM and this Commission.

John Hudson  
President of the Commission
Welcome to the 1st issue 2006 of our ISRM-News-Journal. This issue contains 7 papers, which present current rock mechanics research and rock engineering projects from the European Region.

The extension of the infrastructure within Europe requires a comparatively large amount of tunnels. Peter Zbinden (Switzerland), Walter Wittke/Bettina Wittke/Dieter Schmitt (Germany) and Jakob Likar (Slovenia) present some of these tunnel projects.

Tunneling in swelling rock has been a problem during the past decades. In several tunnels swelling has led to high stresses in the lining resulting to failure or to large heave of the invert. Thus extensive measures to upgrade these tunnels were the consequences. Martin Wittke presents a design concept, which accounts for the swelling phenomenas and results in a safe and even more economic design of tunnels in swelling rock.

J. Christer Andersson and Rolf Christiansson present the current rock mechanics activities carried out in the Äspö Hard Rock Laboratory. Furthermore short introductions about the rock mechanics activities of the Swedish Universities in Stockholm, Lulea and Chalmers are presented.

I would like to thank all authors for preparing the papers and enabling us to publish the present issue of our ISRM-News Journal.

The European Region has 23 ISRM-National Groups (NG) and approximately 2650 ISRM-Members, which amounts to 50 and 54 % of the ISRM-NG's and Members. To get a close contact to the European Rock Mechanics Sections - in my function as ISRM-Vice-President for Europe 2003 - 2007 - I initiated the EUROPEAN-COUNCIL-MEETING's (ECM's). The first meeting took place in Kyoto, Japan in 2004 and the second meeting in Brno, Czech Republic in 2005. The photos in figure 1 were taken during the second meeting in Brno 2005.

ECM's in the future shall take place once a year. Our next meeting is foreseen in Liege, Belgium during the EUROCK 2006-Conference. It is the aim to promote the exchange of information on rock mechanics and rock engineering within the European Countries and the ISRM.

Finally I would like to thank the ISRM-Board for approval of the contents of the present issue of our ISRM-News-Journal, which was given during our ISRM-Board-Meeting in Lisbon at the LNEC in January 2006. Fig. 2 presents the ISRM-Board in front of the Manuel Rocha Memorial located on the grounds of the LNEC.

**Figure 1.**
European Council Meeting (ECM), Brno, 2005

**Figure 2.**
The ISRM-Board at a special meeting in Lisbon, against the background of the memorial to Manuel Rocha at LNEC.
More and more people and goods cross the Alps. Switzerland wants as much as possible of this growing volume of traffic to travel by rail. Construction of the New Rail Link through the Alps (NRLA) sets a milestone in Swiss transport policy and lays the foundation for environmentally compatible management of mobility. AlpTransit Gotthard is creating a flat rail link for future travel through the Alps. At the heart of the new transalpine rail route is the world's longest tunnel – the 57 km Gotthard Base Tunnel.

Transalpine freight traffic by road and rail has increased continuously in the EU and Switzerland. International trade is growing faster than domestic trade. Demand for freight transportation to and from Italy will continue to rise steeply. European freight traffic across the Alps today mainly burdens the roads. Transalpine road traffic doubles every eight years whereas rail traffic remains constant. Raising the weight limit from 28 to 40 tonnes has resulted in fewer trucks bypassing Switzerland via Austria and France. Transit traffic will continue to increase. Freight traffic in the entire Alpine region will grow by as much as 75% by 2010 according to a study by the EU Commission.

If this trend continues it will endanger the quality of the environment for ourselves as well as future generations. Earlier than other nations, Switzerland has therefore incorporated into its constitution a traffic policy aimed at making mobility as environmentally compatible as possible. However, such traffic volumes are more than the 130-years-old Gotthard route can accommodate. Only by upgrading its railway infrastructure can Switzerland meet the rising demand for freight transportation and the increasing needs of customers.

**Passenger traffic**

The new Gotthard railway, along with improvements made within Rail 2000, and thanks to new rolling stock, will bring much shorter journey times. The 3 hours and 40 minutes needed now to travel from Zurich to Milan through the Gotthard on the Cisalpino tilting train will be cut to 2 hours and 40 minutes. Further reductions are entirely conceivable. Rail travel is then a genuine alternative to road and air. The shorter travel times will benefit approximately 20 million people living in the immediate catchment area of the new line through the Gotthard.

International passenger connections between the hubs of Zurich and Milan will be much faster through the Gotthard Base Tunnel. They will bring the centres of southern Germany and the industrial cities of northern Italy – especially its metropolis Milan – much closer together.

Rolling stock will match the new infrastructure. International passenger trains will be more comfortable, faster and quieter. Modern tilting trains, as well as the familiar TGV and ICE high-speed trains, can travel at more than 200 km/h on the new lines, and on existing tracks are up to about 30% faster than conventional trains. Transit freight trains will also be faster and quieter.

**Freight traffic**

Demand for freight traffic in Switzerland will increase by up to 78% by 2030 according to studies conducted by the Swiss Federal Office for Spatial Development. Transit traffic will grow faster than this. The proportion of freight traffic which travels by rail will increase in response to the Swiss traffic policy. Customers will also demand improvements in operations and administration. The future quality of the timetable for freight traffic must be improved, and coordinated with the timetable for passenger trains.
150 freight trains per day cross the Gotthard today. Construction of the AlpTransit Gotthard will increase this capacity to more than 200 trains per day and also allow longer trains. Compared with the present, this will just about double the amount of freight which can be transported to around 40 million tonnes per year.

The flat rail link on the Gotthard route

Construction of base tunnels under the Gotthard and Ceneri creates an ultramodern flat rail link whose highest point at 550 metres above sea level is no higher than the city of Berne. This is much lower than the highest point of the existing route through the mountains at 1150 metres.

Freight trains travelling on the flat route can be longer and pull up to twice today's weight – 4000 tonnes instead of 2000 tonnes. They will be up to twice as fast, too: the fastest freight trains will have a top speed of 160 km/h. Trains like this cannot be used on existing Alpine routes because of the steep gradients and tight curves. When the flat route is complete, it will be possible to transport an equal volume of freight with fewer locomotives and personnel, and less energy.

The Gotthard Base Tunnel

In 1995, when the Swiss Federal Council approved the preliminary plan for the Gotthard Base Tunnel, it spoke in favour of a tunnel system with two single-track tunnels. The two rail tunnels are about 40 metres apart and joined approximately every 325 metres by connecting galleries.

Two double crossovers allow trains to change from one tunnel to the other – which may be necessary to allow maintenance work or if an incident occurs. Trains can change tunnels in the multifunction stations at Sedrun and Faido. These stations also house ventilation equipment, technical infrastructure, safety and signalling systems, as well as two emergency stop stations which are directly linked by separate access tunnels.

The emergency stop stations provide a place for trains to stop in an emergency from where passengers can escape and be evacuated. To reach the other railway tunnel, passengers do not have to
cross railway tracks, climb steps, or use lifts. Should an incident occur, smoke is sucked out of the affected tunnel and fresh air blown into the emergency stop station through the side tunnels and connecting galleries. A slight overpressure is enough to prevent smoke entering the escape route to the unaffected tunnel. From the emergency stop station an evacuation train transports passengers out of the tunnel. If a train stops before it reaches an emergency stop station, passengers can use the connecting galleries to escape to the other railway tunnel.

The choice of the route

Above ground, the choice of route is affected by concerns of local residents as well as political decisions. Geographical aspects, such as the location of towns and villages, as well as hydro-electric reservoirs and access routes to the construction sites, must also be taken into account.

Another important criterion influencing the optimal route for the Gotthard base tunnel was the geology. The Aare and Gotthard massifs are the backbone of the Swiss Alps. Both massifs consist mainly of gneisses and granites. Wedged in between are younger sedimentary rocks, some of which are massively fractured. Because of this, when constructing the Gotthard Base Tunnel, highly diverse rock strata must be traversed. They range from the tough Gotthard granites, through the highly-stressed pennine gneisses of the Leventina, to the butter-soft rocks of the Tavetsch intermediate massif.

Figure 6. Geology

The Piora syncline was a key point in the geology, since its structure and extent were initially unclear. However, four inclined test bores down to tunnel level indicated that conditions at that depth are solid rock with no water pressure or circulation. Subsequent analyses of bore samples, as well as temperature measurements and seismic tests, confirmed these extremely favourable findings for construction of the tunnel.

Squeezing rock conditions in parts of the Tavetsch intermediate massif, on the other hand, require special methods of tunnel construction to be used. Intermediate headings providing additional access to the tunnel from above (shafts) or from the sides (adits) shorten the construction time of long tunnels. The intermediate headings at Amsteg, Sedrun and Faido halve the construction time of the Gotthard Base Tunnel and divide it into five sections: Erstfeld (with the north portal), Amsteg, Sedrun, Faido and Bodio (with the south portal).

Figure 7. GBT Overview

Construction work began on the Piora test bore system in 1993, which in 1998 delivered clear results regarding the geology of the Piora syncline. Starting in 1996, all necessary adits and shafts were constructed. Now, the railway tunnels themselves, the cross-passages between them, and the multifunction stations are being built. In 2015, the world's longest railway tunnel will start to go into operation.

Figure 8. Drilling and blasting method at Faido
The Ceneri Base Tunnel

The Ceneri Base Tunnel traverses many different layers of rock between the north portal at Camorino (near Bellinzona) and the south portal at Vezia (near Lugano). Two single-track tunnels will be constructed which are linked at intervals of 300 m by connecting galleries. Because the Ceneri Base Tunnel is only 15.4 km long, it will have no crossovers or multifunction stations.

Construction of the two single-track tunnels will start in 2006. Opening of the tunnel is scheduled for 2018.

Latest information

AlpTransit Gotthard Ltd. maintains an extensive multilingual website which is continuously updated. At www.alptransit.ch latest information on the status of work will be found, along with many fascinating details about construction of the new Gotthard Rail Link.
9km long Kallidromo tunnel

Prof. Dr.-Ing. W. Wittke
WBI – Prof. Dr.-Ing. W. Wittke Consulting Engineers for Tunneling and Geotechnical Engineering Ltd., Aachen/Stuttgart, Germany

Dr.-Ing. B. Wittke-Schmitt
WBI – Prof. Dr.-Ing. W. Wittke Consulting Engineers for Tunneling and Geotechnical Engineering Ltd., Aachen/Stuttgart, Germany

Dipl.-Ing. D. Schmitt
WBI – Prof. Dr.-Ing. W. Wittke Consulting Engineers for Tunneling and Geotechnical Engineering Ltd., Aachen/Stuttgart, Germany

The 9 km long Kallidromo tunnel of the new highspeed railway line Athens-Thessaloniki, Greece, Tunnel Sections in Squeezing Ground

Abstract: The new highspeed railway line from Athens to Thessaloniki, the approx. 9 km long Kallidromo tunnel, is to be constructed with two single-track tubes. After completion of approx. 1.5 km on either side, the works had to be interrupted in 2002. Difficult heading and failures of the support had to be dealt with in squeezing ground. Design for the remaining tunnel sections was re-done. For the tunnel sections in squeezing ground, a yielding support with a slotted shotcrete membrane and a special type of yielding anchors is foreseen in the new design.

1. Project

The new highspeed railway line from Athens to Thessaloniki, the approx. 9 km long Kallidromo tunnel, is to be constructed (fig. 1). The tunnel consists of two single-track tubes with a distance of the tunnel axes of approx. 35 m, which is planned to be increased to 65 m in the center section of the tunnel. Cross-cuts are planned every 500 m. The tunnel tubes are drained. The height of overburden amounts to up to approx. 530 m.

The first sections of Kallidromo tunnel were constructed according to the shotcrete method. After completion of approx. 2 x 1.5 km on either side, the works had to be interrupted in 2002, since the envisaged construction time and budget were strongly exceeded. This was mainly due to difficult heading and failures of the support in squeezing ground conditions.

Design of the remaining 2 x 6 km was re-tendered. Re-start of construction is planned for the beginning of 2005.

Figure 1. Kallidromo Tunnel, Plan View.

2. Geology

The tunnel sections remaining to be excavated are located in silty clay, layers of the ophiolitic sequence and limestone (fig. 2, ALEXIADOU & MIGIROS 2003).

A structural and mechanical model for the clay was derived from back-analysis of the monitored displacements measured in the already excavated Southern tunnel sections. Homogeneity and isotropic behavior were assumed. Back-analysis lead to a very high deformability (E ~ 60 MN/m²) and a low strength (σ_u ~ 0 to 1 MN/m²). In view of the over-burden height, which amounts to up to approx. 220° m in the corresponding tunnel section, and the low strength of the clay, squeezing behavior is to be expected also for the upcoming phase of construction.

In the area of the layers of the ophiolitic sequence, the tunnel has a height of overburden between approx. 300 and 530 m. The layers to be expected are schistose serpentinite (se.s), serpentinite (se) and to a minor extent schists, cherts and basic lavas. The schistose serpentinite has a distinct schistosity with limited shear strength, which forms the dominant discontinuity, resulting in anisotropic strength and deformability of the se.s. Material properties of the se.s vary. Sections with lower and higher strength are observed. The se reveals basically the same characteristics as the se.s, however, it has no distinct schistosity, and the properties are slightly more favorable. In both layers, shear zones with properties of a cohesive soil
have to be expected on 15 to 20% of the length. As a rule, the thickness of the shear zones varies between 1 to 3 m, with a maximum thickness of 15 to 20 m. In the area of the shear zones as well as in se and se.s with medium to poor properties, squeezing behavior is to be expected.

The limestone has a comparatively high strength and a low deformability. It is partly thickly bedded and partly thinly bedded. Locally highly fractured zones are observed.

3. Cross-sections

The tunnel sections in clay and in the layers of the ophiolitic sequence are planned with a closed invert (fig. 3).

The tunnel sections in limestone are planned with an open invert (fig. 4). In both cases, a clear diameter of approx. 9 m is foreseen.

4. Tunnel sections in clay

4.1 Tunnel sections already excavated

At the southern side, the tunnel has been excavated on a length of approx. 1370 m. The height of over-burden in the section excavated in clay results to approx. 150 m. A vault excavation with a shotcrete membrane of up to 35 cm thickness and extensive anchoring was carried out (fig. 5). The temporary face was supported with glass fibre anchors (ERGA OSE S.A.).

The temporary vault invert of the advancing right tunnel tube had to be repaired after a roof settlement of approx. 25 cm had occurred within approx. 1 month (fig. 6, 7).
Due to this measure, displacements converged. However, as excavation of the second, left tube proceeded, displacements in the right tube increased again remarkably. Thus, the invert was repaired a second time. Again, stabilization of the tunnel was achieved. However, after approx. one month, displacements again increased (fig. 7). One tunnel section collapsed, the remaining sections of the area in question could be filled with sandy gravel in time and thus were stabilized (fig. 6, 8).

Also the sections marked by "repeated repair..." in (fig. 6) were backfilled to avoid collapse. Prior to the interruption of the works these sections were excavated and a stiff support was installed (fig. 6). This was feasible, because large radial displacements already had occurred, before the tunnel was backfilled.

4.2 New design

With the existing design for stiff support, the new excavation and support in the squeezing clay was however not possible. Therefore, the design was redone. In the new design for the tunnel sections in clay (WBI/NAMA 2003), it is accounted for the squeezing behavior by a yielding support and a full face excavation. A slotted shotcrete membrane and yielding anchors are foreseen (fig. 9, 10), both allowing for radial displacements. After the displacements, which are necessary to allow for the formation of an arch in the rock mass next to the tunnel, occurred, the slots in the membrane are closed and the anchors are tied in. The remaining loads can be taken over by the support without failure.

Based on the results of the back-analysis of monitored displacements mentioned in section 2, three-dimensional and pseudo-three-dimensional stability analyses were carried out. An elastic viscoplastic constitutive law was used (WITTKE 2000). The finite element mesh (fig. 11, 12) is finely discretized in the area of the tunnel. The shotcrete segments as well as the slots are simulated. Five
calculative steps were used for the analyses (fig. 13).
After simulation of the in situ state of stresses and
the preceeding stress relief in the area of the tunnel,
excavation and installation of the slotted shotcrete
membrane and the yielding anchors were simulated
in the third step of analysis, followed by an iteration
to simulate the radial displacements. The factor to
simulate stress relief was derived from the above
mentioned back-analysis of the monitored displace-
ments. In the fourth and fifth calculative step, the
closing of the shotcrete membrane and the tying-in
of the anchors are simulated. In the "yielding state",
the yielding anchors are simulated with single loads
equivalent to the yielding load. After tying-in, the
anchors are simulated with rod elements and their
admissible anchor load.

In this way, a realistic simulation of the sequence of
excavation and support, of the radial displace-
ments, the stresses in the rock mass and support and
the stress re-distribution due to the "arching effect"
is possible (fig. 14).

The analyses show that due to the low strength of
the clay and the comparatively high overburden, ra-
dial displacements of 80 to 100 cm, for unfavorable
conditions even up to approx. 120 cm, will be
necessary in order to avoid failure of the support. In
order to allow for such large displacements, a high
number of comparatively long slots in the shotcrete
membrane is necessary. Therefore, existing
solutions e. g. with sliding steel arches (cp.
SCHUBERT 1996 & SÁNCHEZ FERNÁNDES &
TERÁN BENÍTEZ 1994), which allow only for
smaller displacements, cannot be applied. Furthermore, special types of yielding anchors are
necessary, since the calculated

Figure 11. South Heading in Clay, Yielding Support,
Calculative Section, FE-Mesh (WBI/NAMA 2003).

Figure 12. South Heading in Clay, Yielding Support, FE-Mesh,
Detail (WBI/NAMA 2003).

Figure 13. Yielding Support, Calculation Steps 1 to 5
(WBI/NAMA 2003).

Figure 14. Kallidromo Tunnel, "Arching-Effect" (WBI/NAMA
2003).

Figure 15. Slotted Shotcrete Membrane,
Detail Tunnel Roof (WBI/NAMA 2003).
radial displacements extend far into the rock mass such that the steel rod in the anchor’s bond length also experiences large strains. The solution chosen for the slotted shotcrete membrane is shown in principle on fig. 15.

The yielding anchor (fig. 16a) reaches 12 m into the ground. It is a wedge yoke anchor with 4 m bond length. The bond length consists of a special, heat-treated steel which allows for comparatively large plastic strains before failure. For compensation of the radial displacements of the shotcrete membrane, a sliding nut is foreseen, which slides along the anchor rod as soon as the load of 70 kN, considered in the FE-analyses, is reached. The outstand of the an-chor rod is chosen depending on the expected radial displacements. After closing the slots in the shot-crete membrane, the anchors are tied-in so that they reach their full capacity. During construction, the bearing behavior of the anchors is to be monitored. Possibly, fully grouted anchors with a yielding head can alternatively be installed (fig. 16b).

5. Tunnel sections in Serpentine and Schitish Serpentine

As already mentioned, varying ground conditions and a high overburden are to be expected in these tunnel sections. The stability analyses as well as back-analysis of displacements monitored in an already excavated tunnel section in se.s (Northern heading) show that a stiff support with shotcrete and anchors will be sufficient in the areas of se and se.s with good material properties. In these sections, an advancing vault excavation with open invert is foreseen. The temporary face is supported with glass fibre anchors and shotcrete. Locally, an advancing support with mortar spiles is foreseen. However, in the sections with medium to poor properties as well as in the shear zones, a yielding support will be necessary. The required radial displacements amount to up to approx. 60 cm and are thus smaller than in the clay. However, the uncertainty regarding the ground conditions - the approx. 2 500 m long, complex section was explored with 5 drillholes only - as well as the range of change in ground conditions are far higher than in clay so that flexibility and adaptability of the support are even more important. In principle, the same design is foreseen as for the yielding support in clay. In addition, a modified solution with sliding steel arches is foreseen for sections where smaller radial displacements are sufficient (fig. 17).
6. **Tunnel sections in Limestone**

Since the limestone is competent, an unsupported open invert is foreseen in the corresponding tunnel sections (fig. 4). Full face blasting excavation with minimum support by shotcrete and anchors is foreseen where possible. In the more fractured sections, vault excavation with shotcrete membrane and anchors and potentially advancing support with spiles is foreseen.

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Design and construction of new road tunnels for motorways across Slovenia

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Abstract: The past couple of decades we have witnessed the construction of a motorways across the Republic of Slovenia, which began in the 1970's and strongly accelerated after 1992, when the national programme for the construction of motorways in the independent state of Slovenia was adopted. This period is closely linked to the construction of tunnels, as the route along which motorways are constructed generally runs through hilly terrain. The construction of tunnels within the scope of motorways was frequently subject to complex geological and geotechnical conditions. The central and eastern parts of the country are dominated by low-bearing-capacity and tectonically damaged rocks of the Permian-Carboniferous age and younger, the southern and part of the western part of the country are characterized by younger rocks, primarily in the form of limestones and dolomites with varying karst phenomena, and the southern part of the country in Slovenian Istria is dominated by flysch rock. The contribution presents certain aspects of the construction of motorway tunnels, with special emphasis on the description of complex excavation procedures and primary supporting in Permian-Carboniferous rocks.

1. Introduction

Tunnels are important structures in road and railway linkage and represent important technological as well in environmental stuctures. In the future it will be the basis for quality preservation of natural environment with all heritages more and more appreciated by the modern world. Nevertheless, the construction of tunnels and other underground structures means higher costs, if we compare parameters like the price of a motorway per linear meter. The decision of the course of the layout shouldn’t be a matter of discussion in the short term needs, but long term planning, considering those aspects of design that are valid in developed countries. Shutting the eyes from the development, by the West, can’t contribute to incorporation of our country among those who do forward planning.

On the other hand, we can affirm that with technical and technological possibilities considered, the construction of underground structures is possible in exacting geotechnical and other conditions, which directly affects bigger financial charges and construction costs, respectively.

As regards to the above, the demand for quality and goal adjusted research is expressed, from which complete and applicable answers to technical and technological questions of planned construction are expected.

2. General information about motorways across Slovenia

Construction of the 5th and 10th transportation corridor to connect west and east countries in Europe and to connect north and south countries is an essential part of future developing process in the oldest continent. Republic of Slovenia lies in the cross of these corridors and so new transport ways are part of the wide transport infrastructure. Consolidation of the construction process of new motorways happened after 1992, when the national programme for the construction of motorways in the independent state of Slovenia was proven. This period is closely linked to the construction of tunnels, as the route along which motorways are constructed generally runs through hilly terrain. In Figure 1. oil existing and new tunnels are shown. It is clear that many new tunnels can be expect in future, particularly in new motorways and regional roads, which are now in planning the process.

Construction of some tunnels was extremely difficult because bad geological condition, low rock or soil cover, surface objects above tunnels and other reasons have strong influences on construction schedules and are time consuming. The constructions of some of them are shortly described below.
3. Golovec Tunnel

Double tube three-lane motorway Golovec Tunnel of length about 600 m part of a motorway ring around Ljubljana, a capital of Slovenia. Golovec Tunnel was constructed in low bearing Permian-carboniferous rock (Figure 2). The excavation profile was divided into top heading, bench and invert (Figure 5).

Bad geological conditions (heterogeneous and schistose rock) and large excavation profile, together with instability of surface area and variable of primary stress conditions in surrounding rocks, lead to high deformations during the construction, up to 50 cm in average. The problem is solved with adjusting support measures to the in situ determined geotechnical conditions. After this, the resulting progress over 3 m per day on one job site has been carried out. The construction of the Golovec tunnel shows importance of preliminary research and analysis to avoid difficulties in the last phase of construction.

4. Trojane Tunnel

Trojane Tunnel is the longest motorway double tube tunnel in Slovenia (about 3000m each tube). The construction of this tunnel was the most challenging project during motorway cross to date (Figure 3.).
Physical and mechanical properties of the rocks in the Trojane terrain are mainly of Permian-carboniferous origin and spread in an array of different value bands. The terrain consists of claystone, siltstone and sandstone in different forms of primary damage, which is shown primarily in small self-bearing capacity, with more or less expressed rheological properties, and depending on the content of clay minerals.

Geotechnical properties of rocks and soils found in the Trojane ridge are relatively changeable and in some cases highly damaged by tectonics, frequently deviating from typical averages. This fact has been crucial in deciding on the machinery and other equipment, which were used in excavation and installing of the supporting elements. During the excavation, hydraulic hammers were used and where the weak rock was sufficiently soft, also classical excavator for the excavation in bench and invert were used too.

Since the strength of the rocks was extremely low (drilling and blasting were not necessary) it was necessary to build in stronger and consequently stiff support, i.e. a combined supporting system, which allowed suitable reactive support pressure of the supporting system against the pressure of surrounding rocks to achieve stable rock-support system. During the construction, standard supporting elements were used, e.g. shotcrete MB25, rock passive bolts (SN, IBO) with the bearing capacity of 250kN and 350kN, reinforced meshes Q189 and Q283 and steel arch support (TH21, K24, IPE) (Figure 7.). To ensure stable conditions during the excavation, subsidiary support elements were used, as for example steel fore poling rods, steel pipe roof, and temporary invert arch made of shotcrete, expanded elephant foot, micro piles, fibreglass bolts, etc. (Figure 8.) Construction of main and subsidiary support elements was done with machinery.

The supporting system and the system of excavation were adjusted to changing geological and geotechnical conditions, so that the construction was adjusted based on the results of geotechnical measurements and observations. There were frequent cases of the displacement of rocks and changes over time and stress and field deformations. The changes of the displacements of the tunnel wall were quite frequent.
Many difficulties were experienced when the tunnel construction advanced under the Trojane village, because surface subsidence was too high and additional support measures had to be introduced. At some critical places, the overburden was between 5 and 10m. Some objects on the surface above the tunnel were lightly damaged during construction, and only one object (stall) had been heavily damaged because of the combination of extremely bad geotechnical conditions and poor stability of the construction on the surface. Results of measured subsidence of the excavation face were 40% to 50% of total subsidence.

5. Loica Tunnel and Jasovnik Tunnel
Loica Tunnel and Jasovnik Tunnel are located close to the Trojane Tunnel, but the geological geotechnical conditions were extremely different. Especially during Jasovnik Tunnel construction, the drill and blast method had been used in the top heading and in the bench. This method enabled relatively high rates of excavation. The main rocks from east to west part of the tunnel are dolomite and limestone, tectonically damaged, but fair for construction works. Both tunnels Loica Tunnel are about 850m long and Jasovnik Tunnel is about 1700m long, were constructed faster, with less ground movements problems then Trojane Tunnel (Figure 10.).

6. Kastelec Tunnel
The twin tube Kastelec Tunnel (2150m) is a part of the motorway between middle Slovenia and the coastal area. The karst phenomena imbedded in a relatively sound rock matrix is the main characteristic of geological conditions. The intact rock strengths are up to 70MPa, but the interplay of tectonic and karst features in the rock dictated demanding conditions for the construction and approach in design. Regular investigation was carried out on the density of the karst features such as big underground caverns, or presence of abysses but also on the local features of the simple karst weathering. The aim was to pre serve as much as possible of the precious natural environment that included the karst decorated caverns with living underground fauna.

Figure 9. Installation of the face injected rock anchors.

Figure 10. Longitudinal geological section of the Jasovnik Tunnel with the location of the west portals during construction.

Figure 11. Drill and blast pattern.
The construction phases included successive excavation of the tunnel cross profile, which was regularly divided into the top heading and the bench. This was followed by the excavation and construction of foundation slabs and the drainage system at a particular distance. Relatively high advances of excavation and installation of the primary lining were conditioned by careful drill and blast techniques (Figure 11.) so that there were no significant over excavation of the profile. Over the tunnel construction hundreds of karst features have been found, including a large cavern, connected with system of caves. The discovered system of caves is still accessible from the tunnel (Figure 12.).

7. **Dekani Tunnel**

The Dekani Tunnel is located on the Primorska motorway at the Section Klanec – Sermin. The tunnel runs through the geological sequence of flysch along the full 2150m length (Figure 13.). The flysch is best described as a turbidite made of intermittent layers of sandstone and marl. The excavation and the primary support of the tunnel were successfully carried out using standard support measures i.e. shotcrete, wire mesh, steel ribs and rock bolts, depends of rock mass type.

In some sections, the installation sequence of the works was improved by the use of micro fibre shocrete lining, which lowered the costs of excavation and brought about the time and material savings so that the excavation of the tunnel finished 4 months ahead of schedule. The structural works that took place during the construction of the tunnel were also significant. (Figure 16.). Two enlarged cross-tunnel connections were built between the two tubes to improve safety conditions in some areas.

This allows for redirection of the entire traffic in the tunnel in the case of fire, thus contributing to the overall safety measures. The axis of the left tube of the tunnel was positioned in parts to be very close to the surface, reaching up to 6m at some places. At the location of the Zamatavinec depot the left tube of the tunnel outcropped along the 60m long cut, and a cover structure was built (Figure 15.). The difficult morphology at the West portal entrance dictated the elaborate cut and cover section at this location too.
8. Conclusions

The variable geological structure and hilly relief in Slovenia, meant that the construction of the tunnels has been carried out in different ground conditions. This fact has important implications on construction technology used that were adjusted to the local geotechnical conditions.

Relatively rapid changes in geological and structural composition of rock masses through which quoted tunnels were made and rapid changes in primary stress conditions in surrounding rocks demand a level of high safety which usually require support measures, such as thicker shotcrete lining, deeper installed anchoring systems and application of auxiliary support measures like pipe roof, temporary invert arch, elephant foot, etc.

The greatest problems in the construction were caused by primary and other forms of stress in the rocks as well as by the unfavourable position of the schist and bedding regarding the direction of the excavation. Anisotropy of the rocks and their changeability frequently demanded timely measures and the addition of supporting elements.

The instability of the excavation face and increased tension stress in the primary lining was observed during the advancement of the excavation in the west-east direction. It was necessary to ensure suitable stability conditions by weak rock bolts, reinforced meshes and thin shotcrete linings after each phase of the excavation.

Specific conditions of construction tunnels in time dependant Permian-carboniferous rocks are clearer after Golovec Tunnel and Trojane Tunnel were finished. Long term observation of the deformation in the tunnels and on the surface above the tunnels have shown that time dependant deformation fields are essential parts of planning the excavation process of tunnels in rheologically sensitive rocks.

From the Trojane Tunnel experience one can conclude that the level of rigidity of the support structure and the preserving of the excavation face are essential for maintaining predicted surface deformations above the tunnel.

Construction of the Kastelec Tunnel in a karst area, which is built from better quality rocks such as dolomite and limestone, needed specific support measures to bridge karsts pits and caverns and take into consideration other anomaly present in rock structure.

The double tube Dekani Tunnel is the first motorway tunnel built in the flysch geological formation in Slovenia. Drilling and blasting techniques were used for the excavation of the tunnel, while the primary support was installed immediately, after the excavation round was finished. In some sections standard support measures were modified by the use of the micro fibre shocrete lining. This provides a very efficient alternative for the standard primary support, resulting in savings in time, material and consequently reduction of construction time.

Accurate monitoring and joint action of several experts may result in an optimistic forecast in tunnel construction on other motorway sections that are to be build in the next years.

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**Abstract**: Long sections of the tunnels planned for the project Stuttgart 21 are located in anhydrite bearing, swelling Gypsum Keuper, which also contains swelling clay minerals. The fundamentals of swelling behavior of Gypsum Keuper and its analytical description are illustrated. In chapter 3, the support principles for tunnels in swelling rock are illustrated. With the aid of exemplary analyses, which were carried out with a FE-program developed and calibrated by WBI, it is shown that the more economic principle of resisting support can be realized with small deformations, if a layer of competent rock with sufficient thickness is available above the tunnel’s roof as abutment against swelling pressure. For such conditions the principle of resisting support is to be recommended. In addition, there is a chance for a self-sealing effect of the rock mass in the area of the tunnel due to swelling, which would enable more economic solutions.

FE-analyses and observations for the tunnels Heslach II and Wagenburg showed that heaving of the tunnel tubes, which may extend up to the ground surface, results, if the principle of resisting support is applied to cases where leached Gypsum Keuper is located directly above the tunnel’s roof or in the upper area of the cross-section. In such cases the principle of yielding support is to be recommended, if the installation of a slabtrack does not allow for such heavings.

As an executed example for the principle of yielding support, the Freudensteintunnel is illustrated. Further, rules are set up which should be considered during construction of tunnels in swelling rock.

1. **Introduction**

Single-track tunnels with a total length of almost 50 km are planned for the project Stuttgart 21 in Germany (Marquart 2004). The longest of these tunnels is the Fildertunnel with a total length of approx. 2 x 9.5 km (no. 28, Figure 1). 4.3 km of both tubes of this tunnel are located in the swelling unleached Gypsum Keuper. Also three other tunnels of this project are partly located in this rock formation (no. 25 – 27, Figure 1).

Tunnelling in the unleached Gypsum Keuper is very challenging and often lead to damages to the structure and thus to an increase of construction time and costs in the past. Experience in tunnelling gained by WBI in the area of Stuttgart during the past 30 years will surely help to build the tunnels of the project Stuttgart 21 economically and according to schedule (Wittke 2004).

2. **Fundamentals**

In case water gains access to the anhydritic rock of the unleached Gypsum Keuper, the anhydrite is transformed into gypsum. This chemical process leads to a volume increase of the anhydrite of $DV = 61\%$ (Figure 2, Kiehl 1990, Wittke-Gattermann 1998). Tremendous swelling pressures develop, if this volume increase is prevented.

The relation between the swelling pressures and swelling strains can be described by the law given in Figure 3 (Grob 1972, Wittke & Wittke & Wahlen 2004). This one-dimensional swelling law was extended to three dimensions in a way that also anisotropic behavior of the rock can be accounted for (Kiehl 1990, Wittke-Gattermann 1998). Furthermore, the time-dependency of swelling is accounted for in the model so that stability analyses...
Design, construction, suspension and long-term behaviour of tunnels

(continued)

to design tunnels in swelling rock can be carried out (Kiehl 1990, Wittke-Gattermann 1998, Wittke 2003).

3. **Stability analyses and support principles**

Two different support principles are foreseen for those sections of the tunnels of Stuttgart 21, which are located in the unleached Gypsum Keuper (Figure 4). In case the principle of resisting support is used, the internal lining will be designed to withstand the swelling pressure. For the yielding principle, a highly deformable yielding zone is placed underneath the invert of the tunnel. The planned shoulders of concrete make the construction of the yielding zone easier and prevent loading of this zone by the dead-weight of the concrete lining. On the other hand, this shoulder will be highly loaded due to its great stiffness. Investigations carried out by WBI lead to the result, that the shape of the yielding zone given in figure 4 is the optimum with regards to static aspects and construction works.

Both support principles have a different static mode of functioning. The results of FE-analyses for tunnels and the two support principles are illustrated in figures 5 to 8. The given parameters result from comparative analyses for an investigation gallery in Germany, carried out with the FE-program FEST03 (Wittke-Gattermann 1998). In case the tunnel is well covered with competent unleached Gypsum Keuper and water is only available underneath the invert of the tunnel, the invert is subjected to higher bending in case of a resisting support than in case of a yielding support (Figure 5). Heaving of the tunnel cannot be observed in both cases. The high loading of the shoulders of concrete for the yielding principle is remarkable (Figure 6). It leads to high shear forces in the corresponding area of the inner lining. Nevertheless, the bending moments and normal thrust in the internal lining are lower for the yielding principle than for the resisting principle.

In case leached Gypsum Keuper is located above the roof, tunnels constructed according to the resisting principle are subjected to heaving (Figure 7). Due to the low shear strength and Young's modulus, the leached Gypsum Keuper provides only small resistance against swelling pressures. Thus, in this case the load of the internal lining due to swelling is comparatively small (Figure 8). Also the difference between the radial loading on both linings is comparatively small. However, the
heaving of the tunnel and the ground above are much smaller in case the yielding principle is used (Figure 7).

Figure 6. FE-Analyses, intact rock above the tunnel, radial loading.

Figure 7. FE-Analyses, leached rock above the tunnel, displacements.

Figure 8. FE-Analyses, leached rock above the tunnel, radial loading.

Figure 9. Comparison of the two support principles.

Figure 10. Demands on construction.

Figure 11. Urban railway Stuttgart, Lot 12.

The first three lines in Figure 9 illustrate again the described result. However, if the two support principles are compared, one has to account for the higher costs for construction of tunnels according to the yielding principle. Moreover, the yielding zone is very permeable and due to the large swelling strains loosening occurs in the rock underneath. Thus, the chance for self-sealing of the swelling rock and for the corresponding limitation of swelling pressures is only very low in case the principle of yielding support is used (Wittke, 2003).

4. Construction

A basic rule for tunneling works in swelling rock is to avoid water inflow by all means until the internal lining is completed. Therefore, it is essential to observe the rules given in figure 10. If the tunnel is located in the unleached Gypsum Keuper (Anhydrite, Fig. 10) with a sufficient distance from the leaching front, it is possible to keep the rock completely dry during construction, if these rules are considered.

However, if the tunnel is located in the area of the water-bearing leaching front, it will be extremely difficult to keep the anhydritic rock completely dry. In such cases, the water must be collected and discharged carefully. If this fails, temporary anchoring
of the invert and shotcrete support can be installed to keep the heaving due to swelling within acceptable limits until the final lining is installed (Klonsdorf & Schaser 1991).

5. Examples

5.1 Suburban Railway Line Stuttgart, Lot 12
The turning loop of the suburban railway system in Stuttgart, Germany (Lot 12) was constructed in the 1960s (Grüter & Liening 1976, Wittke & Rißler 1976). A long section of this tunnel is located in the anhydritic unleached Gypsum Keuper (Figure 11). The leaching front is located approximately 15 m above the roof. The ground water table is located in the leached Gypsum Keuper (Figure 11).

Construction works of the tunnel were carried out strictly according to the rules given in figure 10. The rock was covered with a 5 to 10 cm thick sealing of shotcrete immediately after excavation. Anchors and steel arches were not used. The tunnel thus was stable with very little support, and the rock was found to be completely dry. The internal lining was designed according to the principle of resisting support with a thickness of 1 m. Up to now, no damages were observed in this tunnel.

5.2 Road Tunnel Heslach II and Tunnel Wagenburg, Stuttgart
The tunnel Heslach II is approximately 1000 m long and is located in the area of the city of Stuttgart in Germany. The maximum overburden results to approx. 91 m (Figure 12). In the middle section of the alignment, the invert of the tunnel is located in the swelling Gypsum Keuper, whereas the upper part of the cross section is located in the leached Gypsum Keuper. A through-going ground water table was not observed, however, in the area of the leaching front seepage water from rainfall was found. The tunnel was built according to the principle of resisting support with an excavated diameter of 12.4 m. The design of the internal lining lead to a 1.8 m thick invert (Figure 13, Beiche 1991). In the course of construction works, heaving due to swelling did not occur. However, in the following 12 to 14 years after construction heaving of the invert was observed as shown in figure 12. Also leveling at the surface showed heaving. The increase of the displacements over the time is illustrated in figure 13. It can be clearly seen that the observations made for the tunnel Heslach II in principle correspond very well with the analysis results described above.
Similar observations were made for the Tunnel Wagenburg, which is located near to the central station of the city of Stuttgart (Witke 2004).

5.3 Tunnel Freudenstein
The Tunnel Freudenstein of the new highspeed rail-way line from Mannheim to Stuttgart is approximately 6.8 km long (Klonsdorf & Schaser 1991, Kirschke et. al. 1991). Over a length of 5 km, the tunnel is located in the unleached Gypsum Keuper (Figure 14). For the major part of this section the leaching front is located well above the tunnel, however, in the areas of two valleys the leaching front is located in the area of the tunnel’s roof. Mainly along these sections water inflow was observed during construction. This is not surprising, because the ground water table is located in the leached Gypsum Keuper, well above the tunnel (Figure 14). The tunnel Freudenstein was constructed according to the principle of yielding support (Figure 15, Kirschke et al. 1991).

6. Summary and outlook
Based on the theoretical investigations and the experience gained from tunnels constructed in the past, the following conclusions were drawn for the design and construction of those tunnels of the project Stuttgart 21, which are located in swelling Gypsum Keuper: The gradient of the Fildertunnel in the un-leached Gypsum Keuper was determined in a way that the water-bearing leaching front is located well above the tunnel. It is expected that this tunnel can be constructed under completely dry conditions and thus it is designed according to the principle of resisting support (Figure 16). Analyses have shown that a thickness of the internal lining of 80 cm is sufficient to withstand the occurring swelling pressure. Moreover, the chance of self-sealing of the rock is apparent and thus, construction of an even thinner lining might be possible (Witke 2003).

For the tunnel to Feuerbach, the principle of yielding support is foreseen to be used over short distances, because the rock cover above the tunnel is not sufficient (Figure 17). In other sections, it is planned to use the cheaper principle of resisting support. However, explorations will be carried out during construction. In case the rock cover is not sufficient to withstand the swelling pressure, it is planned to use the yielding principle also in these sections. Special measures, such as temporary anchoring or yielding support, are also foreseen in case swelling occurs during construction, although it is not expected.

The principles of resisting support and yielding support respectively were presently used for the design of tunnels in anhydritic, swelling rock. In the first case, the internal concrete lining is designed to resist the occurring swelling pressure. In the second case a yielding zone is installed underneath the invert of the concrete lining of the tunnel. This zone leads to a reduction of the swelling pressure and thus can lead to a reduction of reinforcement and thickness of the concrete lining in comparison to the principle of resisting support. It is combined with drainage of the yielding zone to prevent groundwater from reaching the rock above the tunnel roof and thus to prevent swelling of the rock in this area.

For both design principles, the principle of missing support and the yielding principles it is assumed, that water to initiate the maximum swelling load and full swelling respectively is available in
sufficient quantities. Consequently the designed measures have to be carried out over the full length of the tunnel in swelling rock.

Based on observations the hypothesis was made, that in the area of the transition from water bearing to anhydritic rock, self-sealing due to swelling occurs around the tunnel if the resisting principle is applied. As a consequence of this self-sealing effect seepage through the rock parallel to the tunnel and thus also swelling is interrupted at a certain distance from the water bearing formation (Fig. 11).

In a research project carried out by WBI a rock mechanical and hydraulic model and a corresponding 3D-FEM-code have been developed which describe the corresponding phenomena (Wittke, M., 2003). It is expected that the results of this work will lead to remarkable cost savings along with the design of tunnels in swelling rock.

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Figure 11. Phenomenon of self-sealing
Introduction
The Äspö Hard Rock Laboratory (HRL) is owned and operated by Swedish Nuclear Fuel and Waste Management Co, SKB. The HRL provides the opportunity to conduct research and development work in a rock environment similar to the one that will exist in a future repository for spent nuclear fuel at approx. 500 m depth. The HRL has been in operation since 1995. The experimental work in the HRL is focused on two main areas: the retention properties of the rock against the transport of radionuclides, and development, testing and demonstration of methods and equipment for excavation and disposal. The results of research provide important references to the ongoing site investigations for siting the Swedish repository for spend fuel. The testing and demonstration is also an important task in parallel to these investigations. The work currently performed at the Äspö HRL is presented in SKB 2005.

Äspö Hard Rock Laboratory consists of a 3 600 m long ramp down to 450 m level, close to the Oskarshamn nuclear power station. Figure 1 shows the diversity of experiments performed, the surface facility on the island of Äspö, the location of the ramp under the island as well as the start of the TBM part of the ramp at 420 m level. Besides the ramp there is one shaft with hoist and two ventilation shafts on the island.

Geoscience
The geo-scientific programme at Äspö HRL is quite extensive containing the disciplines of geology, hydro-geology, geo-chemistry and rock mechanics. In the following sections some of the rock mechanics work performed is highlighted.

Rock stress measurements
For the site investigations and the interpretation of the site characteristics. The stress conditions in the rock is the parameter which is the most difficult to determine. It is important that the determination has a high accuracy. Because of this, SKB has performed a number of projects in order to:

- Compare different measurement equipment with each other under controlled conditions
- Develop control methods for quality assured results
- Define conditions during which the different methods can be applicable
- Study methods for evaluation, and
- Analyse the accuracy with which stresses can be measured at large depth.

The single largest activity is connected with a field test in two holes drilled perpendicularly oriented in relationship to each other at the 450 m level (Christiansson & Janson 2002). Measurements have been done with three different methods: 2D overcoring, 3D overcoring and hydraulic fracturing.
A Rock Mechanics Descriptive Model
The first model of the geo-scientific conditions was compiled as a prognosis prior the start of the ramping. The result of all collected geo-scientific knowledge was compiled after the ramp had been completed 1995. The different experiments which have been conducted since 1995 have been reported in sub-models. As a first step to update all geo-scientific site characterisations from Åspö a detailed site-specific rock mechanics model was made. It was integrated with a test of SKB’s planned strategy for the compilation of rock mechanics site specific models. The result from the updated model is a characterisation of the rock’s deformation, structural and strength properties given as mean values as a function of depth as well as absolute values close to major deformation zones located outside the HRL. The result is reported in Andersson et al. 2002.

Demonstration experiments
Demonstration experiments are an important part of the works performed at Åspö HRL. One of the most interesting from a rock mechanics point of view is the Åspö Pillar Stability Experiment which verified and expanded our understanding of progressive failure.

Test boring of vertical and horizontal deposition holes with a diameter of 1.75 – 1.80 m have also been performed on a quite extensive scale. The vertical holes have a typical depth of 8.5 m and the horizontal a length up to 95 m.

Åspö Pillar Stability Experiment
To determine the stress level for the onset of dilation, spalling, and the effect of a confinement pressure on the rock mass response the full scale Åspö Pillar Stability Experiment was performed (Andersson & Eng 2005) in an oval drift aligned parallel with δ at 450 m depth. The pillar was created between two 1.75 m diameter 6.5 m deep holes bored in the floor of the drift with a 1 m thick pillar between them, Figure 2. The first hole bored was confined with a 700 kPa over pressure before the second hole was bored. The acoustic emission (AE) system installed prior the boring clearly indicated an effect of the confinement pressure. Almost no events were recorded in the confined hole while spalling occurred along the second hole’s wall down to 2 m depth. The spalling took place where the pillar width was smallest and the tangential stress hence highest.

The stress in the pillar was further increased by heating of the experiment volume with electrical heaters placed outside the pillar. LVDTs for displacement monitoring and Thermocouples were installed before the heaters were powered. The effect to the heaters was adjusted so that thermal expansion propagated the spalling notch from the initial 2 m depth down to 5 m depth where it halted. The acoustic system revealed that the confined hole was stable with very few acoustic events logged which again stated the effect of a confinement pressure.

When the spalling notch had reached 5 m depth the temperature increase was levelled out. At this steady state the confinement pressure was then released in 50 kPa decrements with an AE listening period in between. There was in principal no response in the rock mass until the confinement pressure was 250 kPa. Spalling then initiated in the notch tip in the open hole. The response from the confined hole was very limited also when the pressure was completely released.

The results from the temperature monitoring was used to back calculate the total tangential stress acting along the hole wall at all times. The preliminary conclusion is that the rock spall when the tangential stress is 117 to 128 MPa.

Observations of the chips formed during the spalling process indicate that the failure mode is purely tensile. The edges of the chips are so thin that any amount of shearing would have broken them off. The notch tip is characterized by small thin chips beneath which larger chips form as the notch propagate. After cooling the entire pillar was removed in five large blocks that have been further characterized, Figure 3

In total, 24 instrument positions were used for the displacement monitoring. The monitoring indicated that the rock beneath the propagating notch tip contracts approximately 0.5 mm before the initiation of dilatation. The maximum dilatation measured was 15 mm.
The acoustic system has been valuable when studying the progressive failure. The AE results could not clearly be correlated with the monitored displacements.

References:
Tomas Franzén,
Director of SveBeFo

Introduction
Swedish Rock Mechanics R&D is very much related to applications in infrastructure tunnelling, ore mining and storage of nuclear waste. Most of these works are performed in hard crystalline rock but there are also major projects in sedimentary formations like the City tunnel in Malmö. Several rail tunnels are also under construction in northern Sweden, and the most complex project in the near future is “Citybanan” in Stockholm, a new twin tunnel commuter link under the city including connections to existing metro lines. The northern link of the ring road system is also being started. Swedish mining is in a boom, much as a consequence of the current development in China. Expanding iron ore mining at LKAB, zinc and copper from Boliden mines and a number of new findings, some of them gold ores, characterise the current situation. All these activities have emphasised the need of qualified engineers and R&D in the field of rock engineering. Three university institutions have their main focus in this field with partly different profiles, shortly described below. SveBeFo – Swedish Rock Engineering Research is co-ordinating a research program of common interest to its members, who are clients, contractors, consultants and suppliers in the field of rock engineering. Much of SveBeFo’s research is performed as PhD projects at the universities.

Royal Institute of Technology (KTH)
The Division of Soil and Rock Mechanics is part of the Department of Architecture and Built Environment at KTH and has its main focus on civil engineering applications with advanced field measurements, analytical and numerical modelling, including probabilistic approaches and risk analysis. Fifteen PhD-students are engaged in various research projects. Current rock mechanics research includes development of grouting technology and rock mechanics design, with focus on probability based design methods characterised by the interaction between rock mass and support in underground openings. Head of Division is Professor Håkan Stille.

Probability based design of rock structures
Project leader: Dr Mats Holmberg

The introduction of Eurocode implies new demands and possibilities to use probabilistic methods in rock mechanics design. The observational method represents a formal way in which the design can take into account uncertainties, both in terms of mechanical properties and calculation models. The method has a potential to be used for more efficient design and construction, based on evaluation of statistical distributions of design parameters in an interactive process, where parameters are systematically updated, for example by using Bayesian statistics on new information when available. This methodology is investigated in a research project including an illustrative demonstration for optimising shotcrete support, as well as further development for quantifying statistic distributions of data as input to calculations and evaluation of reliabilities, for example in terms of failure probability.

Figure 1. Frequency diagram
Distributions of the sample mean thickness of the population as a function of the sample size. From planned conference paper by H Stille and M Holmberg, which presents a theoretical model for the relationship between required minimum shotcrete thickness and actual thickness in place.

Figure 2. Testing of bleeding in thin layers of cement grout.

Cement based grouting
Doctoral students: Rikard Godhäll, Almir Draganovic
Grouting of hard jointed rock has been a major research area for the last fifteen years at the division. Swedish Tunnelling Technology is based on the concept of sealing the rock by pre-grouting from the tunnel face as an integrated part of the excavation cycle. The research has been directed towards theoretical understanding and testing of the rheological properties of cement grout.
penetrating rock fractures. Currently two projects are going on. In one project the hydro-mechanical coupling related to high pressure grouting is studied for better understanding of the mechanism of jacking and adequate restrictions in grout pressure. The other project has its focus on the mechanism of bleeding and penetration of cement based grout. The standard testing of today is not relevant for the actual bleeding process in thin rock fractures. Alternative methods for testing or interpretation will be proposed, based on a better understanding of this process. New equipment has also been constructed to study the mechanism of building up filter cakes which must be avoided to improve the penetrability.

**Luleå University of Technology**

The Division of Mining and Geotechnical Engineering is part of the Department of Civil and Environmental Engineering. It consists of the chair of Rock Mechanics and Rock Engineering, and the chair of Soil Mechanics and Foundation Engineering, and includes two Centres of Excellence, the Swedish Blasting Research Centre (Swebrec) and the Centre for Rock Aggregate Research. Professor Erling Nordlund is head of the Division. The research within rock mechanics and rock engineering is focused on (i) Failure processes in natural discontinuities and rock masses, (ii) Deformation processes, (iii) Stability of underground excavations and rock slopes, (iv) Rock mechanics applied to mining, (v) Rock reinforcement, (vi) Blasting, (vii) Rock Aggregates, (vii) Production planning and simulation. Currently there are fourteen PhD-students working within these subjects.

**Hangingwall Subsidence at the Kiirunavaara Mine**

*Doctoral students: Mai-Britt Mose Jensen and Tomas Fernando Villegas Barba.*

LKAB is mining iron ore in Kiruna in northern Sweden. The orebody is about 4 km long, 80 m wide and dipping at 60°. It extends probably down to 2000 m depth. The mining method is sub-level caving which means that ore is removed from a draw point on each sub-level until the ore has been completely caved. As a consequence, caved waste rock fills the void left by the ore extraction. The mine has been experiencing large-scale subsidence of the hangingwall, and the increasing mining depth will result in propagation of surface deformations and cracking toward the railway and the city of Kiruna, situated on this hangingwall side of the mine. A prognosis of future subsidence will require a good understanding of the rock mass behaviour, the failure mechanisms, and the distribution of surface deformation. The objective of the project is to (i) Identify different geological regions with large-scale mechanical behaviour, (ii) Increase the understanding of the mechanics of plastic and brittle deformation zones, (iii) Increase the knowledge about the magnetic and mechanical anisotropy, (iv) Increase the understanding of the stress state and the structural geology through studies of seismic data, (v) Through numerical analyses, observations and measurements identify the main failure modes of the hangingwall (vi) Make prognoses of future subsidence.

**Mechanism of confined sub-level caving blasting by model scale blasting**

*Doctoral student: Daniel Johansson.*

The objective is to understand the controlling mechanisms in choke blasting environments in sub-level caving. In normal bench blasting the reflected stress wave at the bench face contributes to the fragmentation. The caved rock or debris at first acts as a “wave trap”, but also reduces the initial horizontal velocity of the blasted rock slab. If
this latter mechanism is strong enough, an otherwise cracked slab may become immobilised and fail to unravel when the ore loading starts. The approach is to measure fragmentation in model scale blasting under relevant interface conditions. The work is specially aimed at finding relevant cracking and breakage thresholds.

Chalmers University of Technology

The Division of GeoEngineering is part of the Department of Civil and Environmental Engineering. The research in the field of engineering geology is mainly related to ground water and the influence of hydrogeological conditions in civil engineering projects including climatic conditions and anthropogenic effects. Investigations, modelling and risk assessment are basic tools for better understanding of these phenomena. Hydrological effects related to tunnelling has been a major focus at the division, both effects on ground water conditions and sealing of tunnels by grouting. Models have been developed for characterising fractures and the flow of grout material during the grouting process. Head of the engineering geology research group is Professor Gunnar Gustafson and five PhD-students work on projects in this field.

Rock characterisation and grouting trials in hard jointed rock

Project leader: Assistant Professor Åsa Fransson

Grouting trials have been performed in crystalline rock at a depth of 450 m during construction of a 70 meter long tunnel in the Åspö Hard Rock Laboratory. Hydrogeological investigations were undertaken stepwise, resulting in a successive updating of the rock description, followed by grouting design, and prognoses. The application of a coupled methodology for rock characterisation and design meant that, (i) general systematic pre-grouting could be avoided thanks to detailed rock characterisation, and (ii) an early assessment could be made for a suitable grouting methodology. The initial description of rock, based on data from a core borehole, was used for a base design, with two grouting fans. Even though further investigations resulted in design changes along a section of the tunnel, a combination of inflow measurements and pressure build-up tests gave a sound basis for choosing the appropriate grout. Based on inflow measurements, the sealing effects were from approximately 95 up to 99,9 per cent.

Grouting with gelling liquids and models for sealing of narrow fractures

Doctoral student: Johan Funehag

The use of resins and polymers is nowadays seldom accepted in underground construction work, because environmentally safer materials is an important issue. This project aims at understanding and testing the characteristics of gelling liquids and especially silica sol. Field studies have been conducted in Hallandsås rail tunnel and Åspö HRL to verify sealing effects and penetration length in narrow fractures by visual observations in rock cores and hydraulic tests. A 2-D model for calculating the penetration length was developed. Further tests have been done in a road tunnel north of Stockholm where fractures down to 0,014 mm had to be sealed to cope with the specifications. A new concept to determine an effective grouting time has been introduced to be used as a guide for more efficient sealing results. The theoretical basis has been published in Felsbau 2005:3, by G Gustafson and H Stille.
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