

国际岩石力学学会

INTERNATIONAL SOCIETY FOR ROCK MECHANICS

Sociedad Internacional de Mecánica de Rocas

NEWS JOURNAL

www.isrm.net

2009 Annual Review, Technical Articles on China and Rock Dynamics, Invitations to Switzerland and India



Pietre Dure – mosaic inlay of marble and semi-precious stones – Florence, Italy: 1st Annual ISRM Field Trip, September 2009

Annual Review 2009

Information relating to the Hong Kong SINOROCK Symposium, Secretary-General's Report, and much more

Rock Dynamics

Technical articles from the ISRM Rock Dynamics Workshop held in Lausanne, Switzerland

Volume 12, December 2009

See Table of Contents on Page 3

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John A Hudson

Editor's Introduction to this Volume

The ISRM had another excellent year in 2009. Our main international conference was SINO-ROCK2009, held on the University of Hong Kong campus in May. This was preceded by an ISRM Lecture Tour through China with lectures given by Tony Meyers, Resat Ulusay, John Harrison and myself in Beijing, Nanjing, Wuhan and Hong Kong, see page 44.

At the Council meeting in Hong Kong, Xia-Ting Feng of the Chinese Academy of Sciences' Institute of Rock and Soil Mechanics in Wuhan was elected as the next ISRM President for the 2011-2015 period, see pages 10 and 28. His term of office begins immediately after the ISRM 2011 Beijing Congress.

As one of the many initiatives of the current ISRM modernisation programme, the Annual ISRM Field Trip was inaugurated in 2009 with a visit to the Carrara marble quarries near Florence in Italy, see page 22-23. The visit, organised by

Massimo Coli, was enjoyed by all the participants. The 2010 ISRM Field Trip, incorporating visits to ten geological, engineering and cultural sites of interest, will take place on 13-14 of June (see the invitation on page 98), i.e. the two days preceding EUROCK2010 to be held in Lausanne (see also the invitation on page 99).

The main international ISRM meeting in 2010, where the ISRM Board and Council meets, will take place in India in association with the ARMS6 symposium during the last week of October (see page 100, the back page of this Issue).

The work of all the nine ISRM Commissions is progressing well. In this Issue, we highlight the progress of the Commission on Rock Dynamics, and its Workshop which was held in Lausanne in 2009, see the papers in this Issue, pages 72+.

In the last Issue of the News Journal, for 2008, it was noted that, in addition to French and German, the ISRM will be recognising the use of other languages, as an example see the Chinese and Spanish on the front cover of this Issue.

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The 2007-2011 ISRM Board



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**The main thrust of the new ISRM Board is 'modernisation' -
a key element of which is enhanced communication between all ISRM Members.**

**The email addresses of your regional Board representatives,
together with the President and Secretary-General, are given above.
We welcome contact/inquiries from current and potential ISRM Members.**

**Please let us know if you have any suggestions for improving the ISRM.
We will do our best to implement them.**

The 2009 ISRM Year

Prepared by Luis Lamas, Portugal, ISRM Secretary-General (secretariat.isrm@lnec.pt)

2009	ISRM Sponsored Events	Key Events
January		Publication of the hard copy of the <i>News Journal Vol.11</i>
February		FedIGS Board meeting in Cairo
March		Publication of the digital <i>Newsletter No.5</i>
April		
May	<p>Lecture Tour in China</p> <p>SINOROCK 2009, Hong Kong, China</p> <p>ISRM Commission Workshop (Application of Geophysics to Rock Engineering)</p> <p>Short Course on Fracture Geology</p>	<p>ISRM Council meeting in Hong Kong:</p> <ul style="list-style-type: none"> Election of Prof. Feng Xia-Ting (China) as the ISRM President for the term 2011-2015 Dr Z. Z. Liang from China presents 2009 Rocha Medal paper at the Hong Kong Symposium Dr Jan Christer Andersson from Sweden selected as recipient of Rocha Medal 2010 Initiatives for modernisation of ISRM ISRM By-law No. 5 revised
June	Rock Dynamics Workshop, Lausanne, Switzerland	Publication of the digital <i>Newsletter No.6</i>
July		
August		
September	1 st ISRM annual technical and cultural field trip to the Carrara marble quarries in the Florence region in Italy	Publication of the digital <i>Newsletter No.7</i>
October	EUROCK 2009 – Rock Engineering in Difficult Ground Conditions – Soft Rocks and Karst, Cavtat (Dubrovnik), Croatia	
November		FedIGS Board meeting in Ghent
December		Publication of the digital <i>Newsletter No.8</i>

2009 ISRM Membership

Prepared by Luis Lamas, Portugal, ISRM Secretary-General (secretariat.isrm@lnec.pt)

MEMBERSHIP IN MAY 2009

Ordinary - Corresponding - Corporate

ISRM COUNCIL MEETING 2009

Hong Kong, CHINA

Monday, 18 May, 14h00

AFRICA	ASIA	AUSTRALASIA	COUNTRIES	EUROPE	N AMERICA	S AMERICA
0 1 0			Algeria			
			ARGENTINA			7 1 0
		223 6 3	AUSTRALIA			
			AUSTRIA	298 0 0		
	0 2 0		Bahrain			
			BELGIUM	36 1 0		
			BRAZIL			68 0 1
			Bulgaria	0 2 0		
			CANADA		259 2 0	
			CHILE			14 2 0
	502 6 14		CHINA			
			COLOMBIA			14 1 0
			Costa Rica			0 2 0
			CROATIA	159 1 0		
			CZECH REP.	22 0 0		
			DENMARK	3 0 0		
0 1 1			Egypt			
0 1 0			Ethiopia			
			FINLAND	70 0 1		
			FRANCE	171 0 10		
			GERMANY	320 2 6		
21 0 0			GHANA			
			GREECE	131 1 0		
			HUNGARY	10 0 0		
	304 1 0		INDIA			
	27 2 0		INDONESIA			
	102 11 0		IRAN			
			Ireland	0 1 0		
	19 0 0		ISRAEL			
			ITALY	216 3 3		
	384 2 44		JAPAN			
	51 0 2		KOREA R			
	0 2 0		Malaysia			
			Malta	0 0 1		
			MEXICO		13 1 0	
	6 2 0		MIDDLE EAST ASIA			
	6 0 0		NEPAL			
			NETHERLANDS	26 0 0		
		95 1 0	NEW ZEALAND			
0 1 0			Nigeria			
			NORWAY	207 1 2		
			PARAGUAY			6 0 0
			PERU			8 2 0
			POLAND	62 0 0		
			PORTUGAL	141 0 9		
	0 1 0		Qatar			
			RUSSIA	33 1 1		
			Servia	0 1 0		
	62 2 0		SINGAPORE			
			SLOVAKIA	10 0 0		
			SLOVENIA	34 0 0		
276 1 4			SOUTH AFRICA			
	45 0 0		SOUTH EAST ASIA			
			SPAIN	214 3 0		
			SWEDEN	232 0 13		
			SWITZERLAND	161 1 4		
			TURKEY	121 0 0		
			UNITED KINGDOM	276 4 2		
			USA		431 6 4	
			VENEZUELA			11 0 0
0 3 0			Zambia			
297 8 5	1508 31 60	318 7 3		2953 22 52	703 9 4	128 8 1
2 NGs	11 NGs	2 NGs		23 NGs	3 NGs	7 NGs

TOTALS:

Members -

5907

Ordinary

National Groups -

48

85 Corresponding

125 Corporate

Reports of ISRM Board and Council Meetings, May 2009

Luis Lamas, Portugal, ISRM Secretary-General (secretariat.isrm@lnec.pt)

ISRM Board Meeting 2009

This meeting was held in conjunction with the 2009 ISRM International Symposium *Rock Characterization, Modelling and Engineering Design Methods* (SINOROCK 2009), in Hong Kong, on 17 May 2009. The meeting was chaired by the President of the ISRM, John A Hudson, and was attended by all the Vice-Presidents of the respective geographical areas, by the two Vice-Presidents-at-Large, and by the Secretary-General.

The subjects covered were as follows:

- Report by the President on the main decisions taken after the last Board meeting
- Brief presentation by the Secretary-General on finances and budget for 2010
- Co-operation with sister societies - FedIGS, and with ITA
- Summary by the President on the activity of the ISRM Commissions
- Rocha Medal 2010 – selection of the winner
- Report on the progress of the 12th ISRM International Congress to be held in China in 2011 and of the ARMS6 to be held in India in 2010
- Information by the Secretary-General of other endorsed ISRM events: EUROCK2009 to be held in Croatia in October 2009 and EUROCK2010 to be held in Switzerland
- Proposed amendments to ISRM By-law No. 5 *Organisation of ISRM Symposia*
- Discussion on the ISRM endorsement of the 5th *International Symposium on In-Situ Rock Stress* in China in 2010, of the 3rd *Workshop on Rock Mechanics and Geo-Engineering in Volcanic Environments* in Tenerife in 2010 and the EUROCK2012 - *Rock Engineering and Technology* in Stockholm in 2012
- Presentation on the initiatives for the modernisation of the ISRM
- Interim Board meeting and Seminar in Bogotá, Colombia in February 2010

Special attention was given to the initiatives under way to modernise the ISRM, each Board member having reported on the following assigned topics, indicating the strategy for attaining the proposed objectives:

- Prizes and certificates (President)
- Communication with members, Newsletter, News Journal (President, V-P Europe, Secretary-General)

- Availability of literature (V-P Africa)
- Website strategy (V-P Asia)
- Membership numbers and improving the benefits to members (V-P Australasia)
- Major technical issues (V-P North America)
- Strategy for interaction with other Societies (V-P South America)
- Lecture tours and educational material (V-P-at-Large Dr Claus Erichsen)
- Content of ISRM International Symposia and Conferences (V-P-at-Large Prof. Xia-Ting Feng)

ISRM Council Meeting 2009

The ISRM held its Council meeting on 18 May 2009 in conjunction with the ISRM International Symposium 2009 (SINOROCK 2009) in Hong Kong, China. 43 of the 48 National Groups were represented and one Past President was present. The ISSMGE President and most of the ISRM Commission Chairmen attended the meeting as well as the three candidates for the election for President 2011-2015

Report of the President

The President referred to the nine ISRM Commissions currently active and the initiatives to modernise the Society, applauded the success of the electronic Newsletter and noted the increasing number of ISRM Members. The President listed the Conferences and Symposia held so far during his term of office and those already endorsed in the near future.

Reports of the Regional Vice-Presidents

Each Vice-President presented a report on the activities carried out in the respective geographical areas.

Report of the Secretary-General

The Secretary-General presented his report, informing the meeting, besides other issues, on the evolution of membership; on the exclusion of Iceland from the ISRM; on the Rocha Medal winner; News Journal and Newsletter, ISRM website and Virtual Library. This report is included in this Issue of the News Journal, see pages 11-14.

Accounts of 2008 and Budget for 2010

The ISRM accounts of 2008 and the Budget for 2010 were approved.

Approval of Amendments to the ISRM By-Law No.5

The Council approved the revision to the ISRM By-Law No. 5 *Organization of ISRM Sponsored meetings* proposed by the Board. The major changes are: the ISRM will sponsor one regional symposium in each region, each year; there will be a new category of sponsored events, termed *Specialized Conferences*, with a smaller contribution to the ISRM; the ISRM members will obtain a reduction of at least 20% in the fees in all ISRM sponsored events; and the copyright of the proceedings of the International Symposia will remain with the ISRM and may be shared with another organisation.

Announcement of the Rocha Medal 2010 winner

The Council was informed that the Board decided to award the Rocha Medal 2010 to Dr Jan Christer Andersson, for his thesis "*Rock mass response to coupled mechanical thermal loading - Äspö pillar stability experiments, Sweden*". Dr Andersson will receive the award at the 2010 International Symposium in New Delhi, India. The Board also awarded two runner-up certificates - Proxime Accessit certificates - to Dr Yoon Jeoung Seok, from Korea, for the thesis "*Hydro-mechanical coupling of shear induced rock fracturing by bonded particle modelling*" and to Dr Abbas Taheri, from Iran, for the thesis "*Study of shear strength and deformability properties of rock masses by in-situ and laboratory testing methods*".

Co-operation with Sister Societies, FedIGS

The ISSMGE President, present in the meeting, briefly explained the involvement of ISSMGE in FedIGS, the FedIGS Board meetings and the work done by several

Joint Technical Committees and noted that the first meeting of the Liaison Committee was to take place in Antwerp, in November 2009.

The President informed the Council that, as a result of the Memorandum of Understanding signed between ISRM and ITA, a Joint Action Group on Site Investigation Strategy for Rock Tunnels had been created with the task to prepare a guidance document, and three ISRM members had been appointed for ITA Working Groups.

ISRM Commissions

The President informed the meeting of the nine existing Commissions and emphasized their generation of significant new products. Reports on their activity were presented by the respective Chairmen or their representatives:

- Education
- Geophysics
- Mine Closure
- Preservation of Ancient Sites
- Radioactive Waste Disposal
- Rock Dynamics
- Rock Engineering Design Methodology
- Rock Spalling
- Testing Methods

(continued on next page)



Some of the National Group representatives at the ISRM Council meeting in the Hong Kong University Council Chamber room

ISRM sponsored meetings

New Delhi was confirmed as the venue for the 2010 ISRM annual meetings, to be held in October, in conjunction with the 6th Asian Rock Mechanics Symposium ARMS6.

The organisers of the ISRM sponsored events presented the progress on their organisation:

- 19-22 May 2009, Hong Kong, China - SINO-ROCK2009 - *Rock Characterization, Modelling and Engineering Design Methods*: the 2009 ISRM International Symposium
- 29-31 October 2009, Cavtat (Dubrovnik), Croatia - EUROCK2009 - *Rock Engineering in Difficult Ground Conditions - Soft Rocks and Karst*: an ISRM Regional Symposium
- 30 May-1 June 2010, Canary Islands, Spain - 3rd *International Workshop on Rock Mechanics and Rock Engineering in Volcanic Environments*: the first ISRM Specialized Conference
- 16-18 June 2010, Lausanne, Switzerland - EUROCK2010 - *Rock Mechanics in Civil and Environmental Engineering*: an ISRM Regional Symposium
- 25-27 August 2010, Beijing, China - 5th *International Workshop on Rock Stress*: an ISRM Specialized Conference

- 23-27 October 2010, New Delhi, India - ARMS6 - *International Symposium on Advances in Rock Engineering*: the 2010 ISRM International Symposium
- 16-21 October 2011, Beijing, China - *Harmoinising Rock Mechanics and the Environment*: the 12th ISRM International Congress

Application to host the 13th International Congress in 2015

Two applications were received and both were presented to the Council as follows:

- “*Innovations in Applied and Theoretical Rock Mechanics*”, to be held in Montréal, Canada, was proposed by the Canadian Rock Mechanics Association and presented by Prof. Ferri Hassani; and
- “*Rock Engineering - Present Technology and Future Changes*”, to be held in Agra, India, was proposed by the ISRM National Group of India and was presented by Prof. Ramamurthy

The decision on the venue of the 13th International Congress will be taken by the Council in October 2010 in New Delhi, India.

Election of the ISRM President for 2011-2015

The President explained the voting process according to the ISRM Statutes and presented the three candidates, Prof. Xia-Ting Feng from China, Dr Claus Erichsen from Germany and Prof. François Heuzé from the USA, who each gave a five minutes presentation to supplement their website video.

After the vote counting, Prof. Xia-Ting Feng was elected as the next ISRM President for the term of 2011-2015. He will start his term of office after the 12th International Congress of the ISRM, which will take place in Beijing, China, in 2011.

A CV of Prof. Xia-Ting Feng is given on page 28 of this Issue.



Votes being collected by Sofia Meess of the ISRM Secretariat at the Council meeting in Hong Kong

Report of the ISRM Secretary-General for 2009

Luis Lamas, Portugal, ISRM Secretary-General (secretariat.isrm@lnec.pt)

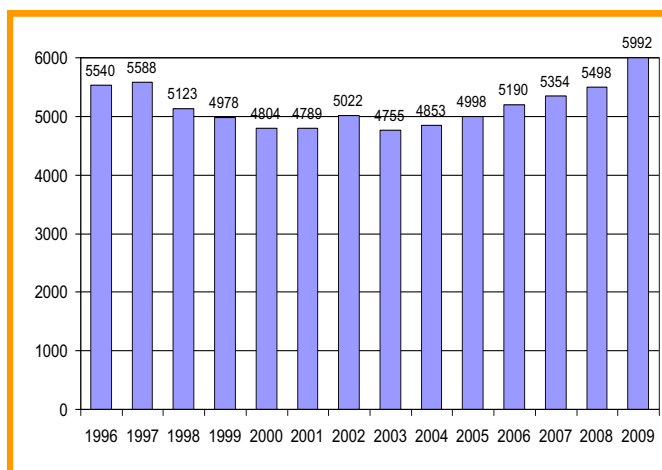
1. National Groups and membership

The current number of ISRM National Groups is 48. The Table below presents the situation regarding ISRM membership, per country and per region, in May 2009. Iceland was excluded from the ISRM owing to lack of contact during the last five years. The present numbers of individual and corporate members are:

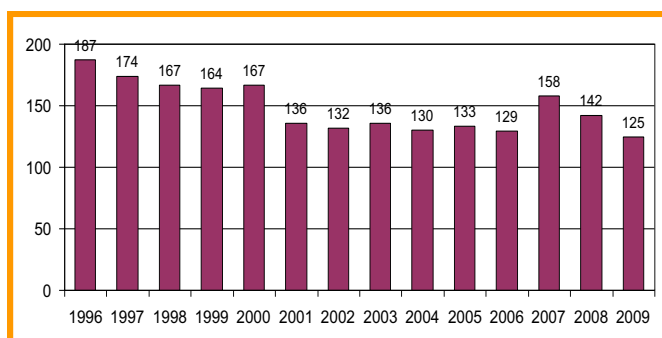
	<u>Individual Members</u>	<u>Corporate Members</u>
Africa	305	5
Asia	1,539	60
Australasia	325	3
Europe	2,975	52
N America	712	4
S America	136	1
TOTALS	5,992	125

When compared with the figures presented at the previous meeting, this corresponds to an increase of 494 individual members (8.2%) and a decrease of 17 corporate members (13.6%). The graphics below present the evolution of the number of ISRM members and National Groups in the last 14 years.

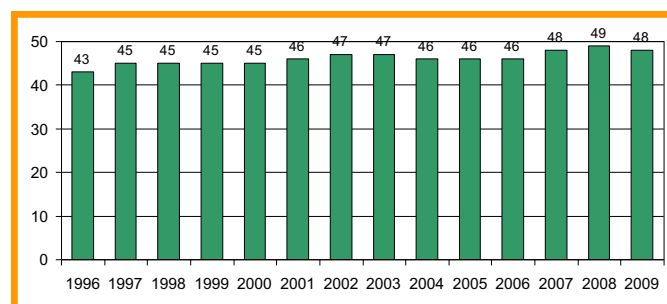
Individual members



Corporate members

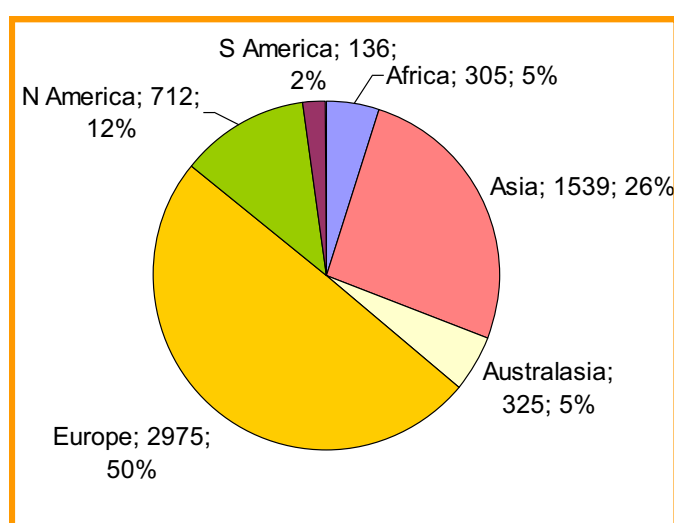


National Groups

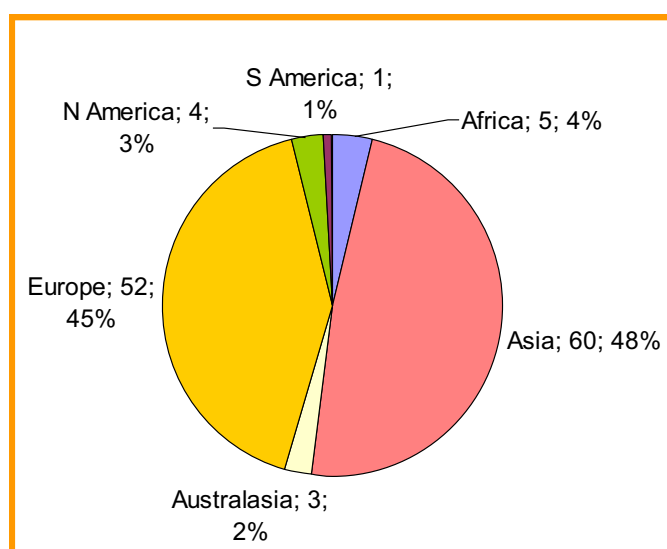


The distribution of individual and corporate members in each geographic region is shown below.

Individual members

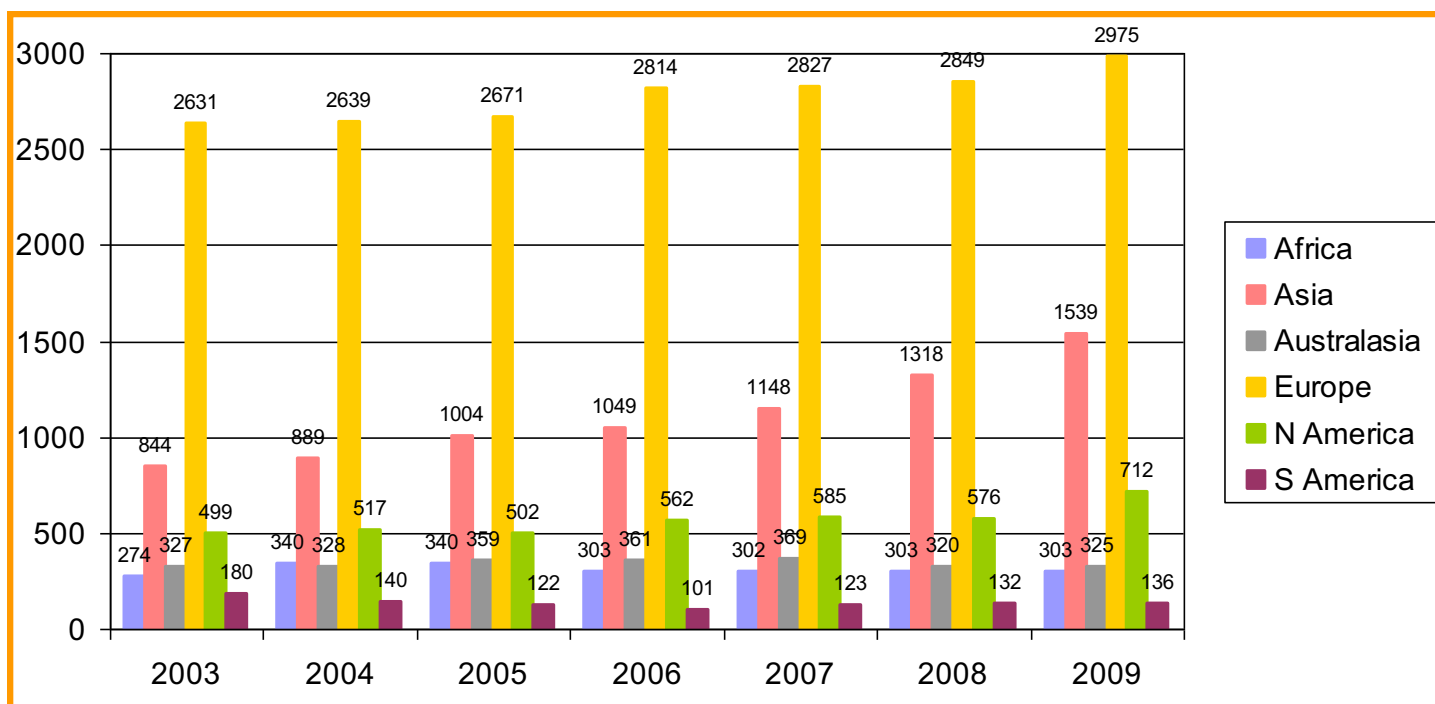


Corporate members



The following graphic shows the recent evolution of the number of individual members in each geographic region.

Individual members



2. Payment of fees

The situation of the National Groups as regards payment of fees is as follows:

Unpaid in 2008: Ghana, Hungary, Mexico and Slovakia.

Paid in 2009 (as at 18 May 2009):

Austria, Belgium, China, Colombia, Croatia, Finland, Germany, India, Iran, Korea, Nepal, Netherlands, Norway, Portugal, Russia, Switzerland, Turkey and UK.

3. Federation of International Geo-Engineering Societies – FedIGS

As already reported, the Federation of the International Geo-Engineering Societies (FedIGS) started its activity in January 2008 under the Chairmanship of Prof. William van Impe for the term 2008-2011. Since November 2008, its Board met once in Cairo, Egypt, on 27 February 2009.

The main items discussed at the meeting dealt with the definition of FedIGS's mission statement, the role to be played by the Liaison Committee composed of representatives of relevant industries and/or institutes, the progress achieved by the 8 Joint Technical Committees (JTCs) and the organisation of the First FedIGS Conference anticipated to be held in Hong Kong in 2012.

4. ISRM-sponsored meetings

The Secretariat provided assistance to the Vice-Presidents and National Groups in the formulation of agreements and the spreading of information regarding the different ISRM Sponsored Meetings.

At the ISRM Council meeting in Tehran, last November, the Council approved the following Symposium as the ISRM International Symposium for 2010: the 6th Asian Rock Mechanics Symposium on *Advances in Rock Engineering*, ARMS6, to be held in New Delhi, India, in October 2010 (see back cover of this Issue).

5. Rocha Medal

During the 2009 International Symposium in Iran, the Rocha Medal Award Committee selected, as the winner of the 28th prize (Rocha Medal 2009), the thesis submitted by Dr Li Gang from China, entitled "Experimental and Numerical Study for Stress Measurements by Jack Fracturing and Estimation of Stress Distribution in a Rock Mass".

This work, selected from among ten shortlisted theses, had been submitted to the Yamaguchi University in Japan. The award was conferred during the 2009 ISRM International Symposium in Hong Kong.

6. ISRM News Journal and Newsletter

One hard copy of the News Journal was published and distributed by air mail to all members of the ISRM. This 100 page Issue (Vol. 11, December 2008) contains the annual review of the Society's activity for 2008 and technical articles from several countries on rock mechanics aspects of the conservation of ancient monuments and sites. An electronic version of this Volume was also posted on the website.

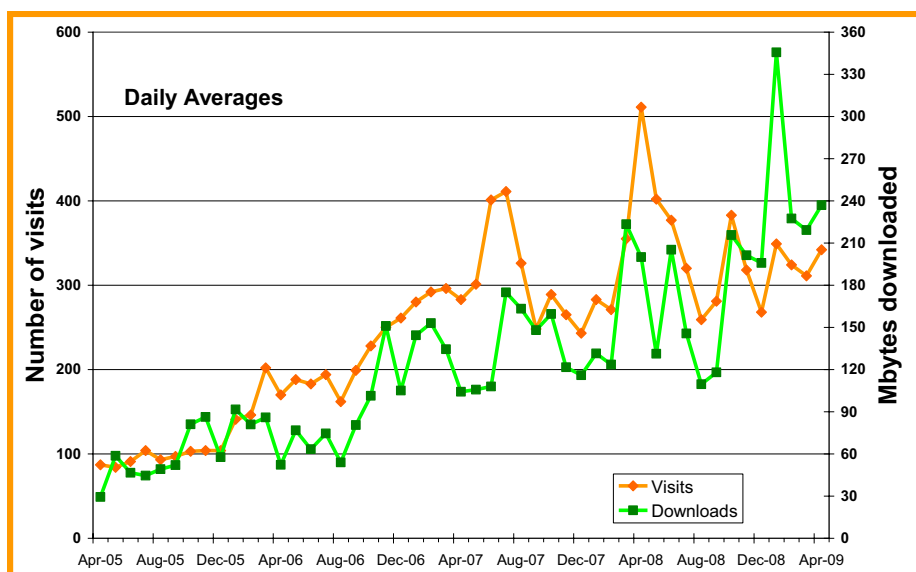
A CD-ROM was prepared and published containing digital versions of all the ISRM News Journal issues since the first one in 1992 and was distributed free to ISRM members, together with the last News Journal Issue, and is available for purchase from the Secretariat.

One issue of the Newsletter was published in December 2008 and another in March 2009. All members registered on the website, as well as all those who subscribed to the Newsletter, receive them by email. The Newsletters are also available for download from the ISRM website.

7. ISRM Website

The website of the ISRM (www.isrm.net), launched on 1 April 2005, is the main means of information on the ISRM and the main channel for communication with the members. Most benefits being offered to the members are available within a password protected members' area. Statistics of the usage to April 2009 are summarised in the graph below.

Statistics of ISRM website usage



A series of downloadable ISRM Lectures on rock mechanics and rock engineering was inaugurated. Dr Erik Eberhardt of the University of British Columbia in Canada kindly donated 15 lectures on rock mechanics and rock engineering, which provide clear overviews of each subject covered. The ISRM is very grateful to Dr Eberhardt for his generosity in providing these excellent, well-prepared lectures. They were made available to members in January and the success of this initiative can be confirmed by the sharp increase in the downloads during that month.

The results of the survey of members undertaken to provide useful directions for the modernisation of the Society and improvement of the Society's activities have been dissected and analysed and can be viewed on the website, together with suggestions by the members of the 'big questions' which still remain to be resolved in rock mechanics.

As another component of the current ISRM Board's modernisation programme, and to ensure that ISRM members have the opportunity to learn about the candidates' experiences and proposed programmes for the office of President, whose election took place at the Hong Kong Council meeting this May, the nomination documents of the three candidates, together with video presentations, could be viewed and downloaded from the ISRM website.

8. Virtual Library

The progress in negotiating the permission from the copyright holders to upload the already digitised ISRM eleven International Congresses and the 31 International Symposia in an online database, is slowly advancing, as well as the negotiation with *One-Petro.org* to enable the use of their platform to store all the ISRM information and to make it available for purchase.

9. Educational and promotional items

As in previous years, the ISRM educational material available from the Secretariat has been in demand, and

Report of the ISRM Secretary-General for 2009 (cont.)

most of it is available in the ISRM website, for free download by the ISRM members.

The “Blue Book”, *The Complete ISRM Suggested Methods for Rock Characterization, Testing and Monitoring: 1974-2006*, launched during the 11th Congress in July 2007, represented, by far, the majority of the sales during this period.

10. Secretariat

The work of the Secretariat staff includes administrative (correspondence, filing, etc.), financial (payments and receipts, accountancy), and secretarial (drafting minutes of meetings, supporting documents, letters) tasks. The Secretary General, with the help of the Webmaster and of the Secretariat, is also responsible for managing the website and, since the beginning of 2008, for producing and distributing the quarterly electronic Newsletters.

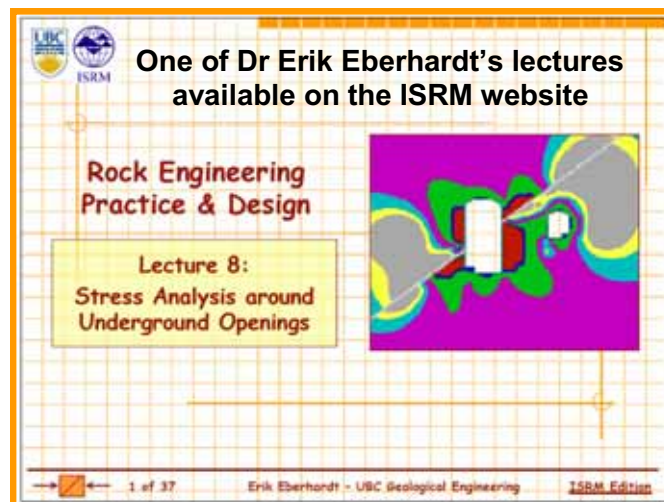
Mrs Sofia Meess was appointed as Executive Secretary of the ISRM and started her activity in the middle of last January and in Hong Kong attended for the first time the annual ISRM meetings.

11. Support afforded

As usual, the Secretariat made ample use, at no charge, of a number of facilities available at the Portuguese National Laboratory for Civil Engineering – LNEC. This included use of office rooms and of other facilities offered to the Secretariat, support in secretarial and book keeping work, telephone and fax, as well as use of LNEC's computer network, namely for internet access and e-mails. This support has long been instrumental to the well-being of the Society and is very much appreciated.

The Secretariat also thanks the Portuguese Foundation for Science and Technology, FCT, for the courtesy in providing a grant to the Society.

12. Final remarks



The life of the Society and the activity of the Secretariat during the period corresponding to this report were marked by:

- implementation of the modernisation initiatives defined by the Board;
- continuation of the trend of an increase in the number of individual members of the Society;
- increase in the website content and the number of visitors and documents downloaded.
- publication of the CD-ROM with all the previous issues of the ISRM News Journal.

Luís M. N. Lamas,
Lisbon, May 2009



Home page of the ISRM website: www.isrm.net

The SINOROCK2009 Symposium held in May in Hong Kong

John A Hudson, UK (john.a.hudson@gmail.com) and Alan Kwong, Hong Kong

Following the first SINOROCK Symposium, which was held at the Three Gorges Dam Project site in China in 2005, the second SINOROCK Symposium was held on the University of Hong Kong campus in May 2009. The Symposium was organized by the International Society for Rock Mechanics, The University of Hong Kong, the Chinese Academy of Sciences and the Chinese Society for Rock Mechanics and Engineering. The venue of the symposium was The University of Hong Kong campus. The main organizing personnel were Xia-Ting Feng, John A Hudson, George Tham and Alan Kwong, with strong support from Aggie Sung.

The aims of the SINOROCK symposia are: a) to follow the rock engineering design process through the sequence of rock characterisation, modelling, and then design; and b) to provide a forum for rock mechanics researchers and engineers from the East and the West to exchange views.

The SINOROCK Symposium was preceded on 18 May 2009 by one Short Course: “Structural Geology - Understanding of Rock Fractures for Improved Rock Mechanics Characterisation” with



On the field trip component of the Fracture Geology Short Course preceding SINOROCK2009, John Harrison explains the engineering significance of rock fractures on site at the Shek O quarry in Hong Kong

lectures by John Cosgrove, John Harrison and John Hudson of Imperial College, UK and Kimmo Kempainen of the Posiva company in Finland. The Short Course included a field trip visit to the Shek O quarry in Hong Kong. The Short Course was well attended by around 40 participants, most of whom can be seen in the two photos below.

The ISRM Board, Council and Commission meetings were held on 17th and 18th May. The records of the Board and Council meetings have been reported by the ISRM Secretary-General, Luis Lamas, on pages 8-10 of this Issue and the reports of the Commission Presidents are also included in this Issue—see the Table of Contents on page 3.

In addition, the 2009 ISRM Chinese Lecture Tour preceded the SINOROCK2009 Symposium – as reported by Meifeng Cai on the activities of



Kimmo Kempainen awaits his turn to lecture



John Cosgrove lecturing on the geological origin of rock fractures during the Short Course that preceded the SINOROCK2009 Symposium

SINOROCK2009 Symposium held in May in Hong Kong (cont.)

the ISRM Education Commission, see page 44 of this Issue.

The SINOROCK2009 Symposium itself took place on 19-22 May. There were eight Keynote lectures – by Zuyu Chen, John Cosgrove, Malcolm Gibson, Bezalel Haimson, Li Gang (Rocha Medal Award), Qihu Qian, Shunsuke Sakurai and Ju Wang.

There were Technical Site Visits in the afternoon of 21 May to: the Rock Cavern on the Centennial Campus of the University of Hong Kong; the Hong Kong West Drainage Tunnel Project; and the Geotechnical Engineering Office, Civil Engineering Development Department, Hong Kong Government.

The Symposium Banquet was held on 21 May 2009 in the floating Jumbo restaurant.

At the Closing Ceremony, the two Best Paper Awards were given for “GIS-Based Approaches to Earthquake-Induced Landslide Hazard Zonation” by Huayang Luo, Wendy Zhou & Scott Huang and “Geomechanical Stability and Integrity of Radioactive Waste Repositories in Salt Rock” by Stefan Heusermann, Sandra Fahland & Ralf Eickemeier.

More than 250 participants from all over the world attended the symposium. One volume of the proceedings containing keynote papers and extended abstracts from all the contributed authors was published in paper format and another volume containing the full papers was published in electronic format within a CD. The papers cover the broad spectrum of progress that has been developed in geo-engineering since the last SINOROCK Symposium held in 2005.



Alan Kwong (on-site organiser) and Wenli Xu (secretary of the CSMRE)



Some of the many speakers at the SINOROCK2009 Symposium

中國岩石 2009



**SINOROCK
emblem**



**Meeting of the ISRM
Testing Methods Commission**



**Meeting of the ISRM
Spalling Commission**



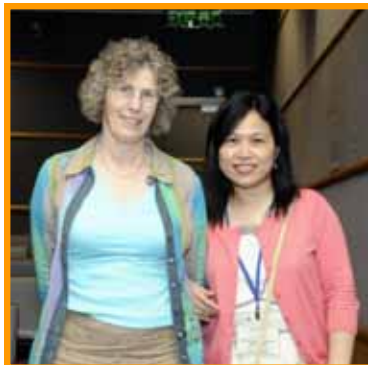
**Xia-Ting Feng and his
wife after becoming the
ISRM President-Elect**



**Qian Qihu, President of the
Chinese Society for Rock
Mechanics and Engineering**



**Li Gang receives the Rocha Award
from John A Hudson**



**Carol Hudson and
Aggie Sung**



**Field trip to the cavern construction on
The University of Hong Kong campus**



**Luis Lamas, Sofia Meess,
Aggie Sung and George Tham**



**The floating restaurant where the
SINOROCK banquet was held**



**A relaxing meal –
George Tham is second from the right**

Rocha Medal Recipient for 2010: J Christer Andersson



The Rocha Medal Award

The ISRM Board decided at its Tokyo meeting in September 1981, to institute an annual prize with a view to honour the memory of Past-President Prof. Manuel Rocha. Following the formation of the ISRM by Prof. Müller, Prof. Rocha organized the first ISRM Congress and he was the leader responsible for transforming this initial international collaboration into an international scientific association, having for the purpose established the fundamental principles which have guided and supported the ISRM activity through the years.

The Rocha Medal is intended to stimulate young researchers in the field of rock mechanics. The prize, a bronze medal and a cash prize, has been annually awarded since 1982 for an outstanding doctoral thesis selected by a Committee appointed for the purpose.

The 2010 Recipient:

J Christer Andersson of Sweden



J Christer Andersson

The recipient for 2010 is Dr J. Christer Andersson, Senior Rock Mechanics Engineer, Luleå, Sweden.

christer.andersson5@vattenfall.com.

Christer was born in 1974 in Kiruna Sweden and obtained his

- M.Sc. in Civil Engineering, Chalmers University of Technology, Göteborg Sweden, in November 1998, and his
- Ph.D. in Rock and Soil Mechanics, Royal Institute of Technology, Stockholm Sweden, in March 2007.

Christer currently works for Vattenfall Power Consultants and was employed by the Swedish Nuclear Fuel and Waste Management Co. at the Äspö Hard Rock Laboratory between 1998 and 2008.

PhD Thesis by the 2010 Recipient:

J Christer Andersson

The title of his PhD thesis is “Rock Mass Response to Coupled Mechanical Thermal Loading, Äspö Pillar Stability Experiment, Sweden”. The following text is a summary of the PhD thesis specially written by the author for the ISRM News Journal.

Spalling will be one of the design issues for the Swedish nuclear waste repository that will be located in hard crystalline rock at approximately 500 m depth. It was therefore decided to perform the Äspö Pillar Stability Experiment to provide an *in situ* estimate of the yielding strength of the rock mass. The general layout of Äspö HRL is presented in Figure 1.

The experiment was designed to concentrate the *in situ* stresses to a level when spalling is initiated and then to monitor the spalling process. At 450 m depth, an oval, 7.5 m high and 5 m wide experimental tunnel was excavated perpendicular to the principal stress direction (Figure 2). Two 1.75 m diameter 6.5 m deep boreholes in the floor of the tunnel formed a 1 m wide pillar.

The first large hole was confined by a bladder with water pressure. Electrical heaters in boreholes were used to slowly increase the stresses so that the spalling propagated along the pillar wall in a controlled manner. The spalling process was monitored by visual observations, displacement and temperature measurements and an Acoustic Emission system.



Figure 1. Äspö Hard Rock Laboratory

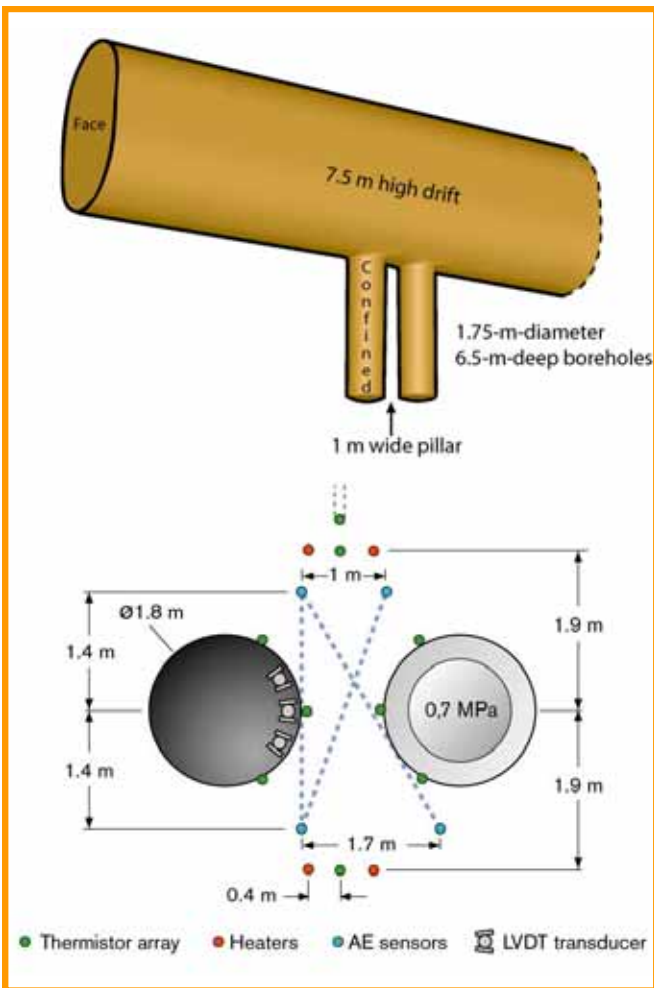


Figure 2. Isometric view of the experimental tunnel and planar view of the instrumentation.

By modelling the combined mechanical, thermal stress in the pillar during the experiment, the spalling strength of the rock could be estimated. The mean value for the spalling strength was found to be $0.59\sigma_c$ (125 MPa) – which is comparable with results from the Mine-By Experiment at the URL in Canada where the spalling strength was estimated to be $0.55\sigma_c$. Other findings from the experiment were as follows.

- Spalling fractures are likely formed by extensile forces and propagate parallel to the maximum tangential stress.
- By applying small confining pressures (a few hundred kPa), spalling can be prevented or stopped if already initiated.
- Spalling clearly initiates when the stress in the rock reaches the spalling strength, but nothing observable occurs at lower stress levels.
- Time dependency for the spalling process was not observed during the experiment.
- The crack initiation stress obtained from strain gauge data when performing uniaxial compressive tests can be used to obtain a conservative estimate of the spalling stress. For this case, the mean crack initiation stress was approximately $0.45\sigma_c$.

After completion of the experiment, the pillar was removed in five big sawn blocks for characterisation purposes (Figure 3).



Figure 3. The boring of the two large holes formed the pillar. The pillar has been removed in five sawn blocks.

6th ISRM Müller Award: Application Deadline

Nominations for the 2011 Müller Award must reach the ISRM Secretary-General not later than 16 April 2010 at secretariat.isrm@lnec.pt

The Award honours the memory of Professor Dr Leopold Müller, the Founder and First President of the International Society for Rock Mechanics. The Award is made once every four years at the ISRM Congress, in recognition of distinguished contributions to the profession of rock mechanics and rock engineering.

Past Recipients:

1991	E. Hoek	CANADA
1995	N. Cook	USA
1999	H. Einstein	USA
2003	C. Fairhurst	USA
2007	E.T. Brown	AUSTRALIA

Candidates are to be nominated by the ISRM National Groups. Each National Group may propose one candidate, with no restrictions on who may be nominated.

Nominations are to be addressed to the ISRM Secretary-General, and shall include the name and address of the nominee and of the nominating National Group; a summary of up to 1000 words describing the nominee's achievements and contributions; and a list of the nominee's publications.

The nominations will be voted by secret ballot at the next Council meeting to be held in New Delhi in October 2010. The selected nominee will receive the award and deliver the Müller Lecture at the 12th ISRM International Congress in Beijing, in October 2011.

All relevant information on the Müller Award, namely regarding the nomination procedure, can be obtained from the ISRM By-law No. 8. on the ISRM website, <http://www.isrm.net>.



Ted Brown's 2007 Müller Award Medal and Lecture Presentation in Lisbon, Portugal at the 11th ISRM Congress



International Society for Rock Mechanics

ROCHA MEDAL 2012

Since 1982 a bronze medal and a cash prize have been awarded annually by the ISRM for an outstanding doctoral thesis in rock mechanics or rock engineering, to honour the memory of Past President Manuel Rocha while stimulating young researchers.

Starting with the Rocha Medal 2010, one or 2 runner-up certificates may also be awarded.

An invitation is now extended to the rock mechanics community, and especially to Faculty members, for nominations for the Rocha Medal 2012.

Full details on the Rocha Medal are provided in ISRM By-law No. 7.



Application

To be considered for an award the candidate must be nominated within two years of the date of the official doctorate degree certification.

Nominations shall be by the nominee, or by the nominee's National Group, or by some other person or organization acquainted with the nominee's work.

Nominations shall be addressed to the Secretary General and shall contain:

- a one page curriculum vitae;
- a written confirmation by the candidate's National Group that he/she is a member of the ISRM;
- a thesis summary in paper and digital formats, written in English, with between 5,000 and 10,000 words, detailed enough to convey the full impact of the thesis and accompanied by selected tables and figures;
- one copy of the complete thesis and one copy of the doctorate degree certificate;
- a letter of copyright release, allowing the ISRM to copy the thesis for purposes of review and selection only;
- an undertaking by the nominee to submit an article describing the work, for publication in the ISRM News Journal.

Application Deadline

The nomination must reach the ISRM Secretary General by 31 December 2010.

Past Recipients

1982	A.P. Cunha	PORTUGAL
1983	S. Bandis	GREECE
1984	B. Amadei	FRANCE
1985	P.M. Dight	AUSTRALIA
1986	W. Purrer	AUSTRIA
1987	D. Elsworth	UK
1988	S. Gentier	FRANCE
1989	B. Fröhlich	GERMANY
1990	R.K. Brummer	SOUTH AFRICA
1991	T.H. Kleine	AUSTRALIA
1992	A. Ghosh	INDIA
1993	O. Reyes W.	PHILIPPINES
1994	S. Akutagawa	JAPAN
1995	C. Derek Martin	CANADA
1996	M.P. Board	USA
1997	M. Brady	GERMANY
1998	F. Mac Gregor	AUSTRALIA
1999	A. Daehnke	SOUTH AFRICA
2000	P. Cosenza	FRANCE
2001	D.F. Malan	SOUTH AFRICA
2002	M.S. Diederichs	CANADA
2003	L. M. Andersen	SOUTH AFRICA
2004	G. Grasselli	ITALY
2005	M. Hildyard	UK
2006	D. Ask	SWEDEN
2007	H. Yasuhara	JAPAN
2008	Z.Z. Liang	CHINA
2009	G. Li	CHINA
2010	J.C. Andersson	SWEDEN

All relevant information can be obtained from the ISRM website, at <http://www.isrm.net>.

Record of the First Annual ISRM Technical and Cultural Field

John A Hudson, UK (john.a.hudson@gmail.com)

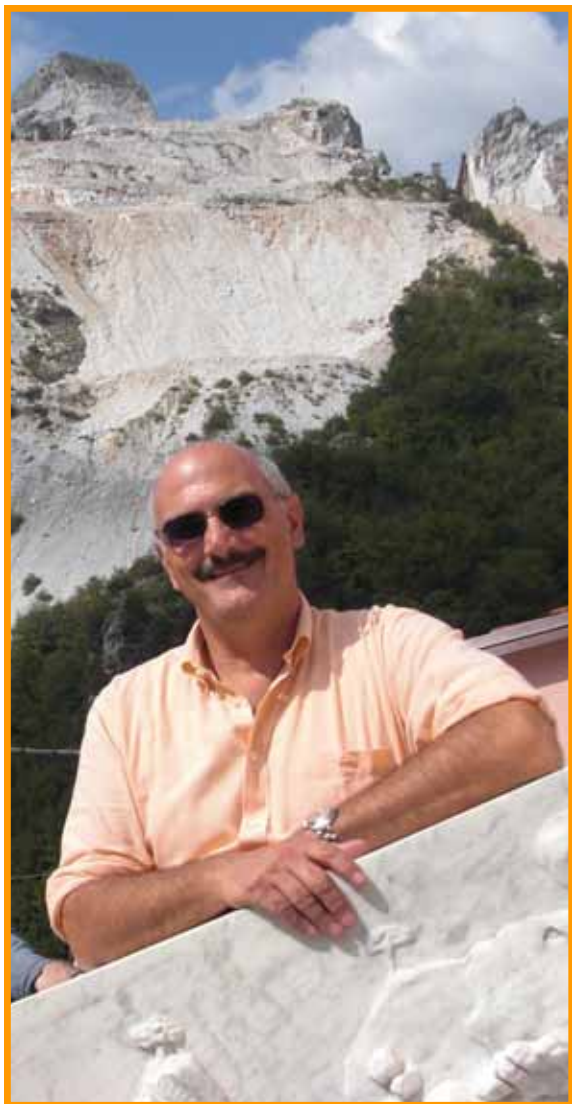
The idea for an annual ISRM Field Trip was generated by the modernisation programme currently being implemented by the ISRM Board. It is intended that these Field Trips should have both technical and cultural aspects — so this first one, originating in Florence, Italy, and visiting the Carrara marble quarries, was an ideal start.

Professor Massimo Coli (see below) of the Department of Earth Science, University of Florence, was the Field Trip Leader supported by his colleague Professor Carlo Alberto Garzonio of the Department of Restoration and Conservation of Architectural Heritage, together with other members of the University of Florence.

There were five main Field Trip visits:

1. Gioia Quarry – Carrara marble
2. Carlone underground mine – Carrara marble
3. Dainese marble Quarrying museum
4. Mine museum and Impero shaft at Gavorrano
5. Temperino disused mine, San Silvestro Park.

22 participants took part in the Field Trip which started in Florence on Monday 21 September and finished also in Florence on Tuesday 22 September 2009.



Professor Massimo Coli
ISRM Field Trip Leader
(with Carrara marble in both the foreground and background)



Section of the Carrara marble quarry showing how the marble is removed in blocks



Marble blocks ready for wire cutting



Close-up of the diamond wire used for cutting the marble blocks

Trip to the Carrara Marble Quarries in Italy: 21-22 Sept 2009



**Concluding one of the excellent Italian meals
— in Colonnata**

On the first day, we visited the Carrara Marble quarries from which Michelangelo took the marble for his masterpieces (see photographs on the left-hand page) and an underground marble mine (see photograph at the bottom of this page).

On the second day, we visited the XXth century disused mine of Gavorrano, and the Etruscan and medieval mine located at the San Silvestro site of the Metalliferous Hills National Park.



**Field trip transport through the Temerino-
Lanzi mine in the San Silvestro Park**

Professors Coli and Garzonio have written a Guide Book for this 1st ISRM Field Trip which is available to ISRM Members from the ISRM web-site. Among related papers of interest is one by Emma Cantisani *et al.* 2009, IJRMMS, 46, on thermal stresses in the Apuan marbles.



Field Trip participants in the underground Carrara marble mine, Italy

Report on the EUROCK2009 Symposium held in Croatia

Ivan Vrkljan, Croatia, EUROCK2009 Chairman (ivan.vrkljan@igh.hr)

EUROCK2009, the 13th EUROCK was organised by the Croatian Geotechnical Society and held in Cavtat, Dubrovnik, Croatia, 29–31 October 2009. It was a continuation of the successful series of regional ISRM symposia for Europe, which began in 1992 in Chester, UK, and will be continued next year as the 14th EUROCK to be held in Lausanne, Switzerland. EUROCK2009 was organised and chaired by Ivan Vrkljan.

EUROCK2009 focussed on recent developments in rock mechanics and rock engineering in difficult ground conditions, including karst. In fact, the karst is an interesting phenomenon, offering images of extraordinary beauty when viewed underground and on the surface; but, on the other hand, posing enormous engineering risks, often bringing unexpected challenges in the course of construction activities.



The fact that most papers submitted for this symposium were related to the theme “Rock properties, testing methods and site characterization” indicates that present-day engineers and scientists are fully aware of the problem of determining the mechanical properties of the rock mass, and that they recognise this problem as a key precondition for successful modelling of every geotechnical assignment in or on rock masses.

Professor John A. Hudson, ISRM President, Dr. Nuno F. Grossmann as ISRM V.P. for Europe and Professor Ivan Vrkljan as Symposium Chairman, contributed to a warm welcome address in the Opening Ceremony.

Seven sections were included with the following topics: geological and hydrogeological properties of karst regions; rock properties, testing methods and site characterisation; design methods and analyses; monitoring and back analysis; excava-



tion and support; environmental aspects of geotechnical engineering in karst regions; and case histories. Keynote lectures were given by Georgios Anagnostou, Giovanni Barla, Nick Barton, Heinz Brandl, Evert Hoek, John A. Hudson, José Muralha and Ivan Vrkljan.

234 participants from all over the world attended from many countries, not only from Europe but also from China, South Africa, Iran, Turkey, Australia, Brasil, Japan, Colombia, Egypt, South Korea, Russia, Nepal, and India.

The volume of the proceedings, edited by Ivan Vrkljan, contains the keynote papers and 129 other papers. It is published by CRC Press/Balkema, a member of The Taylor & Francis Group:

ISBN: 978-0-415-80481-3 (hardback);

ISBN: 978-0-203-85653-6 (eBook), 841 pages.

The proceedings are also available in electronic format as a CD.

There were a variety of supplementary activities: during the symposium, the European Council Meeting was held; 13 companies participated in the Exhibition; and the social programme included two excursions for accompanying persons and a one-day excursion for all participants on the Pelješac peninsula.

The Croatian Geotechnical society extends its warmest thanks to the International Society for Rock Mechanics for the trust that was placed in it when selecting the organiser of EUROCK2009.



Evert Hoek giving his Keynote Lecture



Ivan Vrkljan, Chairman of EUROCK2009

Special thanks are extended to Professor John A. Hudson for his useful suggestions and support during the preparations for the Symposium. We also thank Dr Nuno F. Grossmann, ISRM Vice-President for Europe, and Secretary-General, Dr. Luís Lamas, for their work on the concept and planning of the Symposium. Our gratitude and thanks also go to all the sponsors and especially to the Institut IGH for the general sponsorship. We also thank the Exhibitors who have found interest in taking part in this event, and who have certainly contributed to the success of the Symposium. Finally, we owe special thanks to all authors who shared with us their knowledge and experience – with the purpose of improving current knowledge and expertise in the field of rock mechanics and rock engineering.



Resat Ulusay (President, ISRM Testing Methods Commission, left) and Nuno Grossmann (ISRM Vice-President for Europe, right) enjoy the convivial atmosphere in Cavtat

2009 Activity Report by the ISRM Vice-President for Africa

Francois Malan, S. Africa (Francois.malan@groundwork.co.za)

1. Introduction

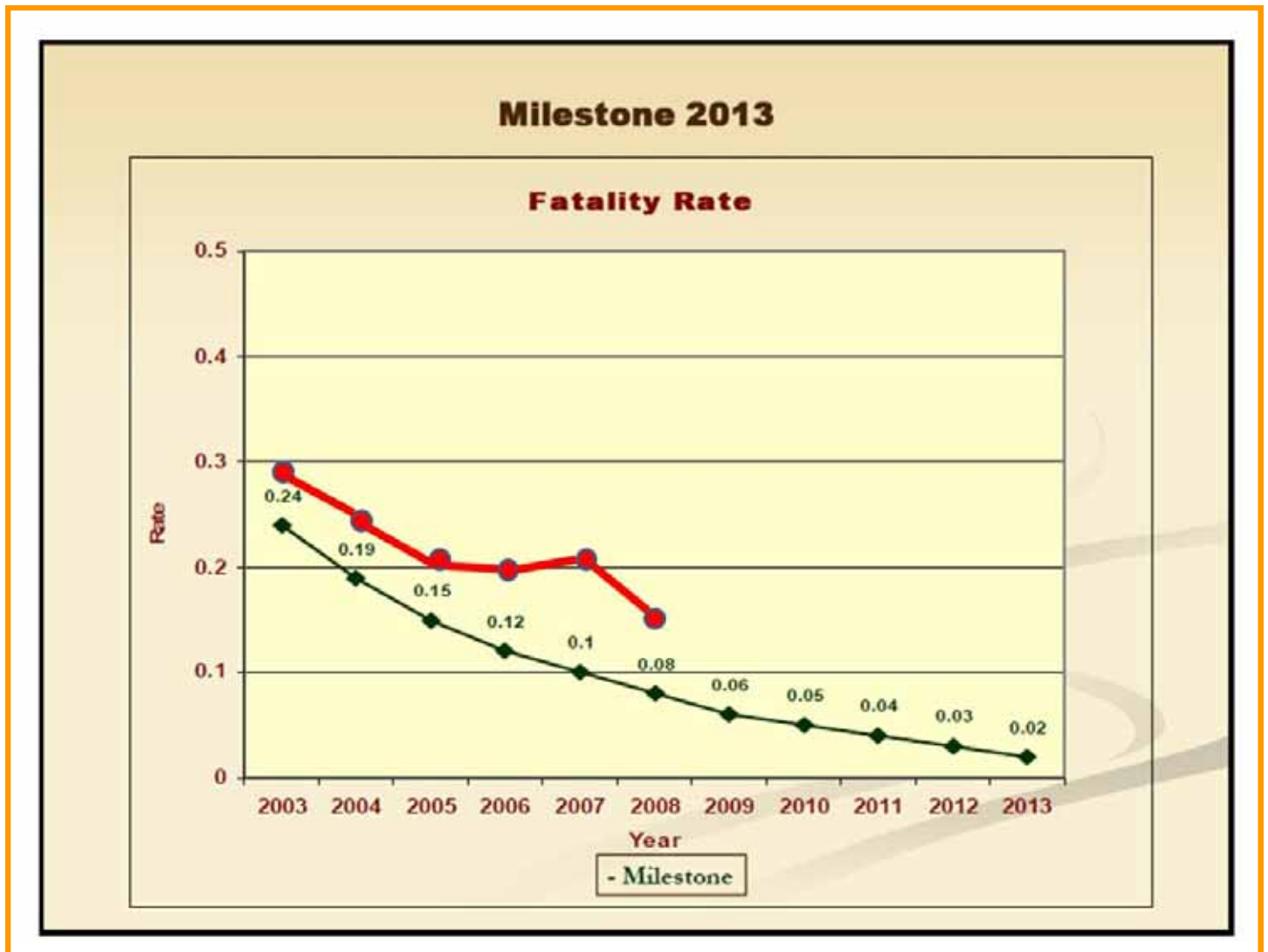
The report below summarizes the ISRM activities for the Africa region for the period of May 2009 to December 2009. With the gradual recovery of the global economy, the outlook for rock engineering activities has improved significantly in the Africa region. This is driven mainly by the improvement in the mining sector as most of the ISRM members on the continent are mainly involved in this area. The South African National Group (SANIRE) nevertheless remains the only active group on the continent. Efforts to establish a new Zambian group were unfortunately delayed as the person driving the process in that country departed. Owing to the large turnover of geotechnical staff in many African countries, the current

feeling is that it might be better to form a larger multi-national ISRM group in Africa. SANIRE might possibly be used as a base for this larger group. Experience has indicated that establishing and sustaining National Groups in different countries on the continent is problematic.

2. Activities of SANIRE

The largest concentration of rock engineering skills in the area is found in South Africa. As reported in May in Hong Kong, it appears as if the trend of emigration of skilled rock engineering personnel to other continents has now been reversed and a number of rock engineers recently returned to the country.

The current membership of SANIRE comprises 382 members, which is a significant growth com-



Decrease in fatality rates in South African mines. The rate is calculated as the fatality rate per million hours worked. The green-black line represents the milestones to be achieved by 2013



Peter Terbrugge was a recipient of the 2009 ARMA Best Paper Award in the category “Applied Rock Mechanics Research”

pared to the number in the previous year (315). The membership currently comprises 23 Fellows, 136 Members, 202 Associate members, 4 Retired members, 2 Corresponding members, 13 Honorary Life Fellows and 2 student members. The six branches of SANIRE in various parts of the country are still active and it encourages and enables active participation from a large number of the members. A key function of SANIRE is still to oversee the examinations for the Chamber of Mines Rock Engineering Certificates – and the interest in these certificates keeps growing.

A key driving force regarding the activities of SANIRE is a national initiative to achieve mine safety performance levels equivalent to current international benchmarks by 2013. The graph to the left illustrates the decrease in fatality rates in recent years and the target set for 2013.

Regarding communication with members, the revamped SANIRE website is now active and readers are encouraged to visit the site at www.sanire.co.za

On a sad note, Dr Martin Pretorius, one of the well-known rock engineering personalities in South Africa and a former SANIRE President and ISRM Vice-President, lost his battle with cancer. He passed away on 29 November 2009. A tribute to Martin is on page 41 of this Issue.

Some of the local SANIRE members, Oskar Steffen, Luis-Fernando Contreras, Peter Terbrugge and Julian Venter of SRK Consulting received the 2009 rock mechanics award in the

category “Applied Rock Mechanics Research” from The American Rock Mechanics Association (ARMA) for their paper entitled *A Risk Evaluation Approach for Pit Slope Design*.

3. Conferences and symposia

The SANIRE 2009 symposium “*Informative Rock Engineering Practice*” was held at the Maccaulei Conference Centre in Vereeniging on 18 September 2009. The Symposium comprised 15 high quality presentations and was attended by 115 delegates. One of the key objectives of the Symposium was to provide a platform for aspiring rock engineering practitioners to present technical papers. Tabang Kgarume was awarded the ISRM ‘Blue Book’ for the best young presenter.



Tabang Kgarume being awarded with the ISRM Blue Book as the best young presenter by Dr Francois Malan

2009 Activity Report by the ISRM Vice-President for Asia

Abdolhadi Ghazvinian, Iran (abdolhadi@yahoo.com)

The election of Professor Xia-Ting Feng as the next President of ISRM for the tenure period 2011-2015 has been the most significant news among the ISRM Asian National Group reports. His election took place during the ISRM Council meeting held in Hong Kong immediately preceding the symposium SINOROCK2009 which took place during 19-22 May, 2009. This honour may be viewed as a sign of the recognition of the extensive rock mechanics activities in Asia. This Asian Report is therefore prefaced with the photo and CV of Professor Feng.



Xia-Ting Feng, China

Xia-Ting Feng was born in 1964, in Anhui, China. He obtained his BSc degree in Mining Engineering (1986), and his PhD in Rock Mechanics (1992), both from the China Northeastern Univ. Between 1992 and 1998, he taught there as Lecturer, Associate Professor, and Professor. During this period, he spent about 2.5 years at the Univ. of Witwatersrand, SA, at Imperial College, UK, at Lille Univ. of Science and Technology, France, at the National Inst. for Resource and Environment, Japan, at the Royal Inst. of Technology, Sweden, and at the Univ. of Oklahoma, USA. Subsequently, he permanently joined the Chinese Academy of Science's Inst. of Rock and Soil Mechanics in Wuhan, where he is now Director-General. He is also Director-General of the State Key Lab. of Geomechanics and Geotechnical Engineering.

He has been an active member of the ISRM since 1995 through the Chinese Society for Rock

Mechanics and Engineering (CSRME), having been President of the ISRM NG China (2004-2007). Currently, he is ISRM Vice-President at Large, Co-Chairman of the ISRM Commission on Rock Engineering Design Methodology, and a Member of the ISRM Commission on Testing Methods, as well as Vice-President of the CSRME. He is the Editor-in-Chief of CSRME's Chinese Journal of Rock Mechanics and Engineering, a Member of the Editorial Board of the International Journal of Rock Mechanics and Mining Sciences, and Member of the Advisory Board of the International Journal of Analytic and Numerical Methods in Geomechanics.

He is the author of 6 books and more than 200 papers, in both Chinese and English. He has two main research interests: intelligent rock mechanics and engineering; and coupled thermo-hydro-mechanical-chemical processes in rock masses.

As mentioned and forecast in my earlier report, dated Nov. 2008, ISRM membership in Asia is rapidly increasing and this is due to the scope and importance the region is gaining. A concise report of activities, forwarded by the ISRM National Groups in Asia, for the year 2009, is given below.

Activities of ISRM National Groups in Asia

China

The China National Group is represented by the Chinese Society for Rock Mechanics and Engineering (CSRME) and currently has 502 individual members and 13 corporate members. A brief note of its activities during the specified period is summarised as below:

An International Workshop was organised for Jin Ping II on the Safety of the Deep Tunnels at the Jinping II Hydropower Station, China, in March 31-April 2, 2009. From all over China and the Hong Kong region, 240 delegates attended the conference, which included the fields of rock engineering, rock mechanics, earthquake prediction, railway engineering and hydropower.

The ISRM-Sponsored International Symposium on Rock Mechanics was successfully held on 19-22 May 2009 at The University of Hong Kong,

China. The aims of the SINOROCK symposia are: a) to follow the rock engineering design process through the sequence of rock characterisation, modelling, and then design; and b) to provide a forum for rock mechanics researchers and engineers from the East and the West to exchange views. More than 250 participants from all over the world attended the symposium, see pages 15-17 of this Issue.

The 3rd ISRM Rock Mechanics Lecture Tour in China from 5-19 May 2009 was organised. Prof. J. A. Hudson, Dr. John P. Harrison, Dr. Tony Meyers and Prof. Resat Ulusay gave lectures in Beijing, Nanjing, Wuhan and Hong Kong, i.e. four cities. The lecture was based on the content of the two books by John A. Hudson and John P. Harrison which have been translated into Chinese (“Engineering Rock Mechanics 1: An Introduction to the Principles” and “Engineering Rock Mechanics 2: Illustrative Worked Examples”, see page 44.

The China National Group has also been successful to organise the Third International Conference on “New Developments in Rock Mechanics and Engineering & Sanya Forum for the Plan of City and City Construction” on May 24-26, 2009, at Sanya, China, with 7 keynote speeches which was attended by more than 50 participants from all over the world.

The ISRM NG China celebrated its 30th Anniversary in August 2009, where John A. Hudson gave a speech to congratulate the NG China.

The 7th International Symposium on Rockbursts and Seismicity in Mines took place on 21-23 August 2009 in Dalian, China. This symposium series provides every four years a framework for scientists, engineers and other professionals to report and discuss the most recent results of research studies and applications in mine seismicity. The forum explores the advances and current status of numerical rock modelling, rock mechanics and microseismic technology and their use in industry. It also searches for new potential solutions to the understanding and monitoring of the dynamic rock mass response to mining. More than 300 participants from all over the world attended this conference.

The CSRME hosted the 7th Session of the Annual Meeting of the Chinese Association of

Science and Technology (CAST), on 8-10 Sep., 2009, in Chongqing, China and organised a National Workshop for Jinping I on the Safety of the Deep Tunnels at Jinping I Hydropower Station, China which took place on 6-9 Nov., 2009.

The 12th ACUUS Conference (ACUUS2009), was organised on 18-19 November 2009, in Shenzhen, China with the title “Using the Underground of Cities for a Harmonious and Sustainable Urban Environment”.

Preparations for the ISRM2011 Congress: The 4th ISRM2011 Organizing Committee meeting was held on 16 May 2009 in Hong Kong. The ISRM2011 website was established: www.isrm2011.com

An anniversary conference for Wenchuan Earthquake on Rock Mechanics (25-29 April, 2009) was also organised

India

The India National Group is represented by more than 366 individual members and has been very active in organizing various activities. A brief glance of its activities during the reporting period is summarised below.

- Organised a Seminar on tunnelling techniques for construction of underground structures for the Army, 7-8 May 2009, Udhampur (Jammu & Kashmir), India.
- Organised two workshops of two days each on “Rock Mechanics and Tunnelling Techniques” in two extreme eastern and northern provinces of India, along with Technical tours.
- Organising the ISRM International symposium 2010 and 6th Asian Rock Mechanics Symposium (ARMS2010) for October, 2010. The first bulletin is being circulated. A separate website for the event with domain name www.arms2010.org will be operating soon (see the back page of this Issue).
- Organised a Workshop on “Applications of Rock Mechanics – Tools and Techniques”, on 5-7 November 2009, Nagpur (Maharashtra).
- To hold a Seminar on “Meeting the Rock Mechanics Challenge of Deep Underground Mining”, 17-19 December 2009, Dhanbad (Jharkhand).

2009 Activity Report by ISRM Vice-President for Asia (cont.)

- The Indian National Group of ISRM and the Central Board of Irrigation & Power (CBIP) are jointly hosting the ISRM International Symposium 2010 and 6th Asian Rock Mechanics Symposium during 23-27 October 2010 in New Delhi (India). The first bulletin has been circulated. A separate website for the event with domain name www.arms2010.org has been made operative.
- Nomination of Dr. G.S.P. Singh, Lecturer, Department of Mining Engineering, Banaras Hindu University, India, for submission to the ISRM Rocha Medal 2010 for his thesis on "Caveability Assessment and Support Load Estimation for Longwall Workings in India".
- The Indian National Group of ISRM and the Central Board of Irrigation & Power (CBIP), the Secretariat of the Indian National Group of ISRM, is revising the Manual on Rock Mechanics, published in 1988, and propose to release the revised manual during the ISRM International Symposium 2010 which is also the 6th Asian Rock Mechanics Symposium.
- The Indian National Group of ISRM and the Central Board of Irrigation & Power (CBIP) are jointly bidding for hosting the 13th Congress of the ISRM. The Congress is proposed to be held in Agra in November 2015. The proposed theme for the Congress is "Rock Engineering – Present Technology and Future Challenges". If successful, this would be the first Congress in India after 49 years since the first congress of ISRM which was organised in Lisbon (Portugal) in 1966.

Iran

The Iran National Group represented by the Iranian Society for Rock Mechanics (IRSRM) has currently increased its member strength from 38 to over 100 and has been very active in promoting the concept of rock mechanics and its inevitable application in conducting various rock mechanics and rock engineering projects throughout the year, especially, after conducting the International Symposium 5th Asian Rock Mechanics Symposium, ARMS5 in November, 2008. The summary of its activities is given below:

- The IRSRM has published two seasonal newsletters (autumn and winter, 2009) in Per-

sian covering the following matters: a) Rock Mechanics and Rock Engineering Activities in Iran and b) New Policy for conducting workshops and short courses with a view towards contributing to industry's requirements.

- As per the IRSRM new guidelines, fresh membership identity cards have been issued to all IRSRM members throughout the country with necessary directions and links to improve and speed-up the interactions between the NG and its members so as to transmit the latest innovations and changes in the field.
- IRSRM Board New Approval: The office tenure was extended from 2 years to 3 years. In addition to existing membership categories, the 'Fellow Members Category' has also been introduced to expand the membership umbrella and to honour the devoted members. Therefore, the IRSRM hereafter shall host the 5 following categories: i) Fellow Members, ii) Members, iii) Affiliated Members, iv) Student Members, and v) Corporate Members.
- The IRSRM General Assembly was held on 24th June, 2009, wherein various important decisions were made with respect to the IRSRM Manifesto.
- New members elected for the Board of Directors of the 7th Period of the Iranian Society for Rock Mechanics (IRSRM) have been approved by Ministry of Science, Research and Technology of Iran on 13 September, 2009. Prof. Abbas Majdi was elected as President.
- A new website providing a wide range of information is under construction to facilitate access to the ISRM and IRSRM programmes, news flashes and other information relating to other fields of rock mechanics.
- Programming, planning and scheduling the IRSRM 4th National Conference for May, 2010.

Israel

The Israel National Group is represented by the Israel Rock Mechanics Association (IRMA). The Group has provided its Activity Report as below.

- An international research seminar on "Shear physics at the meso scale in landslide and

earthquakes mechanics” was conducted on 21-25 January in Ein Gedi on the shores of the Dead Sea. 40 invited speakers from Israel and abroad participated. The proceedings of the above seminar have been published.

- Two rock mechanics sessions were held during the 2009 annual meeting of the Geological Society of Israel between 31 March – 2 April, 2009 at Kfar Blum.
- 12 professional presentations on rock mechanics and geological engineering issues were given by IRMA members and these were attended by a large number of members of the Geological Society.
- A Workshop was conducted on shear physics at the meso-scale in landslide and earthquake mechanics, see <http://www.ortra.com/shear/>
- The Israel NG held its annual professional meeting during the annual meeting of the Geological Society of Israel (GSI) that took place on 31 March - 2 April, 2009.

Japan

The Japanese Committee for Rock Mechanics (JCRM) with its 363 ISRM individual members and 46 corporate members has been very active and has organised various activities during the reporting period. A summary of these is given below.

- Organised the 12th Japan Symposium on Rock Mechanics in which 144 papers were presented.
- Made several important publications on rock mechanics and rock engineering, especially the publication of International Journal JCRM Vol. 3 , 4 and 5 with a Special Issue on Geophysics.
- Rock Net mails (Nos. 214-258) have been distributed to Japanese members and other recipients.
- Newsletters (Nos. 88-9) have been published and distributed to the Japanese Members.
- A CD-ROM titled ‘Rock Mechanics 08’ has been composed and distributed to Japanese Members.
- No.1 (Special Issue on Collaboration and Engineering Education in Asia) has been

published on the website <http://rocknet-japan.org/journal/Articles.html>

- JCRM Awards for 2008 have been conferred to 4 distinguished works in Rock Mechanics and Rock Engineering in Japan.

Korea

The Korea National Group, with 1200 members and 100 ISRM members, is represented by the Korean Society for Rock Mechanics (KSRM). The Korea NG has been very active and organised various activities, as outlined in the attached activity report submitted by the Korea NG. The activities during the reporting period are summarised below.

- Special issue: KSRM opened three Korean sessions and 5 English sessions where all presentations, discussion and announcement are conducted in English. The English sessions were opened first at the previous autumn Symposium in 2007.
- Organized the autumn Symposium in October, 2008 and special National Congress in January, 2009.
- Organized spring symposium in March, 2008.
- Made several important publications on rock mechanics and rock engineering, especially the publication of the Journal in two languages.
- Supporting and involved in the organisation of the 12th ISRM Congress.
- Organised the autumn conference in conjunction with the “Korea-Japan Joint Symposium on Rock Engineering,” and a total of 54 papers from Korea and Japan were presented.
- During the year 2009, KSRM published six issues of the Journal of Korean Society for Rock Mechanics, which is also called “Tunnels and Underground Space”.
- The Korean National Group has also started publishing a bi-monthly ‘webzine’ named ‘U-Space’, which is an electronic newsletter distributed via e-mail and which is also available on the KSRM website.
- In addition to technical meetings and publications, a number of mountain climbing and golfing events were hosted by the social clubs

2009 Activity Report by ISRM Vice-President for Asia (cont.)

within KSRM, which gave excellent networking opportunities for members.

- KSRM will celebrate its 30th anniversary in 2011, and the preparation of a White Book is underway as a long-term project led by the White Book Committee.

Middle East Region

The Middle East Regional Group is represented by the Middle East Society for Rock Mechanics, based in Abu Dhabi, United Arab Emirates. This regional group was affiliated to ISRM last year. The activities during the reporting period have not been reported by the Regional Group.

Indonesia & Nepal

No report has been received from the Indonesian and Nepal National Groups so far.

Singapore

The Singapore National Group is represented by the Singapore Society of Rock Mechanics and Engineering Geology (SRMGE). The Singapore NG has increased its membership to 65 compared to its 40 last year. As mentioned in their report, the Singapore NG has been active in organising various activities as outlined below.

- Organised a two-day Workshop on Norwegian Tunnelling Technology and Practice on 17-18 Feb. 2009.
- Organised the 4th Annual General Meeting (AGM) on 18th March, 2009 in the Hotel Intercontinental Singapore and discussed various key issues.
- The SRMEG is co-organiser of the 12th ISRM Congress with the China NG to be held in Beijing in October, 2011 and has to shoulder many important responsibilities in this respect.
- The Singapore National Group has organised an International Conference on Discontinuous Deformation Analysis 2009 (ICADD-09) on 25-27 Nov. 2009. The conference has received a warm response from different countries, especially from China, Japan, Iran and Singapore.
- Established an interest group on Singapore Geology with the goal of establishing an

Engineering Geological Office for collecting and updating Singapore geology.

- The Singapore National Group also supported the “Geo-Chiangmai” conference organised by the CI-Premier of Singapore held in Dec., 2008, in Thailand.

South East Asia

Thai Rock Mechanics has been active as outlined in their activity report below.

- The Second Thailand Symposium on Rock Mechanics (Thai Rock 2009) represents a continuing mission of the Thai leading academic institutions to promote the significance and development of rock mechanics knowledge and profession in Thailand and neighbouring countries.
- A one-day short course on the 3D Lidar Scanner for Rock Mass Classification preceded the conference and was lectured on by Prof. John M. Kemeny.

Outlook in Asia

The trend and attraction of researchers, engineers, and other corporate sectors towards the Asian region has provided importance to the rock mechanics and rock engineering disciplines. The upward trend of expansion and progress in the activities of the National Groups as described in this report is clearly perceived via the ongoing/incoming years which are witnessing various international events in Asia, especially in China, India, Iran, Japan, Korea and Singapore.

In addition, there are many national and local conferences and symposia planned by the National Groups and Commissions. Efforts to establish ISRM National Groups in other part of Asia, including the Philippines and west and middle Asia, is our future strategy.

2009 Activity Report by ISRM Vice-President for Australasia

Tony Meyers, Australia (tony@rocktest.com.au)

Membership

Australia	223
New Zealand	96
Total:	319

Events held by ISRM-related groups

The following rock mechanics related events were organised in 2009 by local Chapters of the Australian Geomechanics Society and the New Zealand Geotechnical Society.

Topic	Presenter	Date	Location
Distinct modelling of slope stability	C Coll	19 Feb 2009	Brisbane Aus
Vampire Rock avalanches, Mnt Cook Nat Park	S Cox	25 Feb 2009	Otago NZ
In-filled joint model in the design of tunnel support	D Olivera	3 March. 2009	Newcastle Aus
Rock logging	Various	27/28 Mar 2009	Perth Aus
Rock slope remediation	C Thorley	16 Apr 2009	Melbourne Aus
A practical guide to abandoned mine subsidence assessment	D Knott	20 May 2009	Melbourne Aus
Seismic source analysis	J Hengesh	9 Jun 2009	Perth Aus
East coast landslides	Maunsell	28 Jul 2009	Auckland NZ
Abbotsford Landslide revisited	G Hancox	22 Jul 2009	Wellington NZ
Rockslide dams	J Bryant	20 Apr 2009	Canterbury NZ
Baseline reports for underground risk management	J Rozek	12 Aug 2009	Melbourne Aus
Tunnels – Experience from Hobson/Rosedale	Connell Wagner	25 Aug 2009	Auckland NZ
Foundations in rock	C Haberfield	27 Aug 2009	Canterbury NZ
		25 Aug 2009	Auckland NZ
Mine remediation	R Rule	17 Sep 2009	Brisbane Aus
Sharing geo-eng data	D Toll	23 Sep 2009	Perth WA
Seismology and earthquake engineering	Various	24 Sep 2009	Adelaide SA
Kapiti Views Subdivision - Subdivision design & construction in geologically hazardous terrain	N Peters	30 Sep 2009	Wellington NZ
Geotechnical risk	T Chapman	22 Oct 2009	Brisbane Aus
Tunnelling in Australia	L McQueen	30 Oct 2009	Brisbane Aus
Pike River Mine access tunnel	E Giles	6 Oct 2009	Canterbury NZ
		20 Jun 2009	Auckland NZ
		28 Oct 2009	Wellington NZ
The SRM Criterion and its application to the stability of deep slopes in open pit mines	J Read	19 Nov 2009	Brisbane Aus

Each of these 2 hour events attracted between 20 and 60 geotechnical practitioners. The events were provided to attendees at no-cost.

Rock mechanics related events held by non-ISRM related groups

Workshop Topic	Date	Location	Provider
Ground vibrations – Blasting & seismicity & its effect on ground control	29-30 Oct 2009	Launceston Aus	EAGCG
Geotechnical engineering in open pit mines and CSIRO open pit mining geomechanics	9-12 June 2009	Brisbane Aus	ACG
Blasting for stable slopes short course	14-15 July 2009	Perth Aus	ACG
Selecting the appropriate ground support	13-14 May 2009	Cairns Qld Aus	EAGCG
Managing seismic risk in mines	24 March 2009	Perth Aus	ACG
Practical rock mechanics in mining short course	25-26 March 2009	Perth Aus	ACG
In-situ rock stress measurement and mine seismicity		Auckland NZ	IESE

- ACG - Australian Centre for Geomechanics
- EAGCG - East Australian Ground Control Group
- IESE - Institute of Earth Sciences and Engineering

Each of these events attracted approximately 50 and 100 rock mechanics practitioners. The average registration fee for these events was between €175 and €570. No discount is provided to ISRM members.

General Issues

The Regional VP continues to communicate with local members at every opportunity. Recent communications included:

- ISRM RockNotes articles for quarterly Australian Geomechanics Journal and New Zealand Geomechanics News.
- Emailing links to ISRM News Letter.
- Liaisoning between members and Secretariat re: membership issues, addresses or web-site problems etc.
- Emailing information concerning the Society or general rock mechanics issues of interest.

The VP provided the opportunity for Australian members to contribute to the ISRM Presidential election process. Members were emailed and asked to vote for their preferred candidate on the basis of the candidate's videos and documentation. 20% of members responded. The overwhelming number of these respondents indicated that they appreciated the opportunity to be involved.

One submission was received for consideration for the 2010 Rocha medal, Dr Rhett Hassel from Curtin University with the PhD thesis title "Corrosion of Rock Reinforcement in Underground Excavations".

The NZGS is hosting the 11th Congress of the International Association for Engineering Geology and the Environment (IAEG) in Auckland in September 2010.



Underground over-coring rig used by Dr Rhett Hassell for his PhD research "Corrosion of Rock Reinforcement in Underground Excavations" undertaken at the WA School of Mines, Curtin University, Kalgoorlie, Australia.

2009 Activity Report by ISRM Vice-President for Europe

Nuno Grossmann, Portugal (grossmann@lnec.pt)

In 2009, only one European ISRM-Sponsored Regional Symposium took place, namely, EUROCK 2009, the Symposium on Rock Engineering in Difficult Ground Conditions – Soft Rocks and Karst, which was held in Cavtat (Dubrovnik) Croatia, on 29-31 October 2009. This Symposium was a great success, having attracted more than 200 participants. The technical component included 9 special lectures and the oral presentation of around 70 papers, in parallel sessions. The proceedings have been produced, both as a paper volume with more than 800 pages, and as a CD. A well prepared social programme allowed the participants a very agreeable come-together, and gave them the opportunity to visit the Dubrovnik region. This EUROCK Symposium is also described on pages 24-25 of this Issue.

The European Council Meeting 2009 took place in association with EUROCK2009, and, among other issues, analysed the implications of the change in the rules for the selection of ISRM-Sponsored Meetings, in accordance with the decisions taken at the ISRM Council Meeting 2009, held in Hong Kong, China, on 18 May 2009. For the European ISRM-Sponsored Regional Symposia 2012, 2013, and 2014, the respective complete candidatures have to be received at the ISRM Secretariat, in Lisbon, in time to be submitted, respectively, to the ISRM Board meetings in Bogotá, Colombia (February 2010), in New Delhi, India (October, 2010), and in Beijing, China (October 2011).

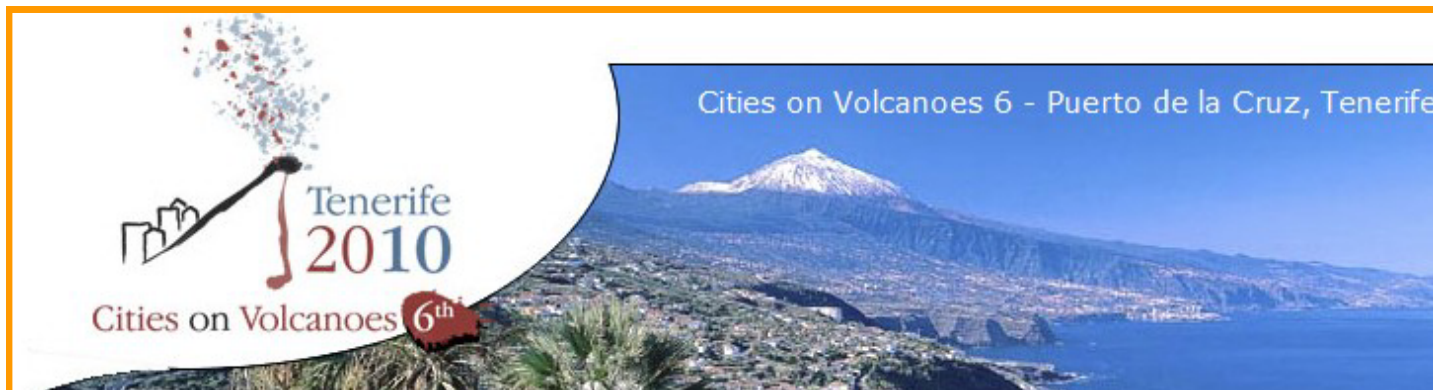
The ISRM was also formally invited to make a presentation at the Get Underground meeting in Helsinki, Finland, on 4-5 November 2009, co-organised by the Finnish Tunnelling Association (FTA), having its 35th anniversary, and the ISRM National Group of Finland led by Erik Johansson.

For 2010, the ISRM Board approved, as the European ISRM-Sponsored Regional Symposium, EUROCK2010, the Symposium on Rock Mechanics in Civil and Environmental Engineering, to be held in Lausanne, Switzerland, on 15-18 June 2010, see also page 99 of this Issue. Note that the European Council Meeting 2010 will take place on that occasion.

The ISRM Board further approved, as an ISRM-Sponsored Specialized Meeting, the 3rd International Workshop on Rock Mechanics and Geo-Engineering in Volcanic Environments, organised by the ISRM National Group of Spain, to be held in Puerto de la Cruz (Canary Islands), Spain, on 31 May to 1 June 2010, in conjunction with the International Congress “Cities on Volcanoes 6 – Tenerife 2010”.



Discussion in one corner of the European Council Meeting in Croatia



Information about this meeting is available at www.citiesonvolcanoes6.com

2009 Activity Report by ISRM Vice-President for N. America

Derek Martin, Canada (derek.martin@ualberta.ca)

Canada

The Canadian Rock Mechanics Association (CARMA - <http://www.carma-rocks.ca/>) serves as the ISRM National Group for Canada. Members are from CARMA's two constituent groups: the Rock Mechanics Division of the Canadian Geotechnical Society (CGS); and the Society for Rock Engineering of the Canadian Institute of Mining and Metallurgy (CIM).

A combined total of 259 CIM (163) and CGS (93) members paid for membership into CARMA and the ISRM in 2008, whereas a combined total of 237 CIM (152) and CGS (85) members paid for membership into CARMA and the ISRM in 2009 (the 2009 count is based on October numbers but few new members are expected to join in November and December).

CARMA's recent and ongoing activities have included sponsorship and organization of the 3rd *Canada-U.S. Rock Mechanics Symposium & 20th Canadian Rock Mechanics Symposium*, held in Toronto, Canada on 9-15 May 2009, which included over 90 papers, and attracted an international audience of 200 participants.

Also, The Canadian Rock Mechanics Association (CARMA), comprised of the Rock Engineering Society (RES) of the Canadian Institute of Mining, Metallurgy and Petroleum (CIM) and the Rock Mechanics section of the Canadian Geotechnical Society, has proposed to host the 13th ISRM Rock Mechanics Congress in 2015 in Montreal, Canada. A proposal package was presented during May, 2009, at SINOROCK2009, the 2009 ISRM-Sponsored International Symposium in Hong Kong, by Dr. Ferri Hassani, of McGill University, who will be the Chair of this proposed event if Canada's submission is successful.

The decision on whether Canada will be selected will be taken at the 2010 ISRM symposium in India. This initiative has the support of Canadian industry, the Federal Government of Canada, the Provincial Government of Quebec, and of academia from across Canada. Furthermore, the Canadian Institute of Mining, Metallurgy and Petroleum (CIM) has offered to collaborate fully and to contribute to the organization of this event. Using a successful outreach model that has been deployed by the CIM for the

past several years, the national and provincial associations that relate to the earth sciences sector will also undertake participatory measures that can enhance effective marketing campaigns in order to boost attendance.

Awards

Peter Kaiser (CEMI) was awarded the Rock Mechanics Award from the Rock Engineering Society of CIM during the RockEng09 symposium held in Toronto.

Douglas Stead (Simon Fraser University, Burnaby, BC) was awarded the Canadian Geotechnical Society's 2009 Franklin Award for contributions made in the fields of rock mechanics and rock engineering. Established in 1993, the Award honours the past President of the International Society for Rock Mechanics (ISRM), John A. Franklin.

Projects

Peter Kaiser (CEMI) is instrumental in developing a multidisciplinary international research project that focuses on studying fault slip mechanisms *in situ*.

CARMA has formed a partnership with the Canadian Institute of Mining, Metallurgy and Petroleum (CIM) to support future Canadian rock mechanics symposia by organising the meetings in conjunction with the CIM's Annual Conference and Exhibition. This partnership will help to strengthen and highlight the important role of rock mechanics in the continuing success of the Canadian mining industry. After Toronto 2009, the next event will be in 2012 in Edmonton, Alberta.

United States

The American Rock Mechanics Association (ARMA, www.armorocks.org) continues to help shape and respond to issues of national interest and concern, including carbon sequestration, energy resource production, civil engineering infrastructure, and research and development through the proposed Deep Underground Science and Engineering Laboratory (DUSEL). These opportunities were discussed (and in one session debated) at the 43rd US Rock Mechanics Symposium in Asheville, North Carolina in June 2009.



2009 ARMA Fellows (l to r): Don Banks, 2008 Fellow Sid Green, Ahmed Abou-Sayed, Derek Elsworth, 2008 Fellow Jean-Claude Roegiers. John A Hudson and Wolfgang Wawersik, not pictured, will receive their medals at the 44th US Rock Mechanics Symposium in Salt Lake City in June

Stimulating keynote addresses were delivered by Derek Elsworth, who presented the first MTS Lecture on *Geomechanics Through the Alche-*



Martin Suarez

mist's Prism – Complex Process Couplings Related to Deep Geologic Sequestration and Energy Recovery; Sid Green on *Rock Mechanics/Geomechanics from an Energy Perspective*; William Ayers on the *National Energy Technology Laboratory's Extreme Drilling Laboratory*; and Rick Wooten on the *Geology and Geohazards in Western North Carolina*. The ARMA Fellows discussed *What Does the Future Hold for Rock Mechanics*. Finally, Maurice Dusseault and Jean Claude Roegiers took part in the first *Bicker and Beer* debate! Presentations can be found at http://216.119.67.159/resources_asheville2009.html

Martin Suarez from Olympus High School in Salt Lake City was recognized at the Asheville 2009 banquet as the youngest presenter at a US rock mechanics symposium. His paper, developed with his father, Roberto Suarez-Rivera, was titled *Water Imbibition in Oilfield Rocks and Applications to Oil Recovery*.



Cezar Trifu and Vladimir Shumila receive the 2009 Case History Award from Awards Committee chair

ARMA Fellows

Five ARMA members were elected to join the ARMA Fellows at the Asheville symposium. The ARMA Fellows program recognizes individuals who have achieved outstanding accomplishments in the area of rock mechanics and who have contributed to the professional community through ARMA. The 2009 Fellows are: Ahmed Abou-Sayed, Don Banks, Derek Elsworth, John A Hudson and Wolfgang Wawersik.

Awards

The 2009 ARMA Awards were also given out at Asheville. Recipients were:

- Rock Mechanics Research Award: *Laboratory Study of Hydrothermal Deformation in Unconsolidated St. Peters Quartz Sand*; Stephen Karner, Andreas Kronenberg, Judith Chester, Frederick Chester, Andrew Hajash.
- Applied Rock Mechanics Research Award: *Fractured Rock Hydromechanics: from Borehole Testing to Solute Transport and CO₂ Storage*; Chin-Fu Tsang, Jonny Rutqvist, Ki Bok Min.
- Applied Rock Mechanics Research Award: *A Risk Evaluation Approach for Pit Slope Design*; Luis-Fernando Contreras, Peter Terbrugge, Oskar Steffen, Julian Venter.

- Case History Award: *Microseismic Monitoring of a Controlled Collapse at Ocnele Mari, Romania*; Cezar Trifu, Vladimir Shumila.

Other ARMA Activities and News

- The National Science Foundation, Office of International Science and Engineering and the Directorate for Engineering awarded ARMA a two-year grant to establish an exchange program with rock mechanics faculty in Afghanistan. Four faculty from Afghanistan will attend the 44th US Rock Mechanics Symposium in Salt Lake City 2010.
- The ARMA Digital Library now includes most U.S. rock mechanics symposium proceedings. OnePetro manages the library for the Society of Petroleum Engineers. Corporate subscriptions are now offered. See: www.onepetro.org
- ARMA continues to work with the National Science Foundation on the proposed Deep Underground Science and Engineering Laboratory (DUSEL) that, if funded, will be located at the former Homestake Mine in Lead, South Dakota. Geomechanics and rock engineering will be one component of the laboratory facilities, as will be the construction of the underground facilities in the jointed rock mass.
- ARMA subscribes to the Engineering and Science Career Network, a service that links employers with potential employees. Many engineering and science professional societies are part of the network. If you are looking for work or need to hire, check out: <http://careers.armacocks.org/>
- At its meeting in October 2009, the Board of ARMA elected the following officers:
 - President: Azra Tutuncu
 - Vice President: Mark Zoback
 - Treasurer: Bill Dershowitz
 - Secretary: Rico Ramos
 - Chair of the Board: Sarah Wilson (as immediate Past President)
 - Executive Committee Member at Large
 - Member: David Yale

2009 Activity Report by ISRM Vice-President for S. America

Álvaro J. González-García, Colombia (ajgon@cable.net.co)

Rock mechanics development in the South American region was originally mainly associated with mining, railway, dam and roadway engineering. However, due to significant reserves of gas and oil in some of the countries in the region, such as Venezuela, Brasil, Ecuador, Bolivia and Colombia, rock mechanics activities as related to oil engineering have recently shown an increase.

1. ISRM National Groups and Members

At present (December, 2009) the South American Region has 7 National Groups with more than 110 ordinary members and 1 corporate member (Petrobras from Brasil). Of the National Groups, only Chile and Peru do not have a website.

The Vice-President began communication with the Costa Rica Geotechnical Association and with some Bolivian engineers and intends to become in touch with Ecuador, Panama and Mexico.

2. National Group Activities

Argentina The Argentinian Society of Geotechnical Engineering (SAIG) organised the 3th South American Young Geotechnical Engineers' Conference from March 30th to April 1st, 2009 in Cordoba; this meeting included some papers on rock mechanics. The SAIG is organising the XX Argentinian Soil Mechanics and Geotechnical Engineering Conference which will take place in Mendoza, from 6th to 9th of October, 2010, having sessions on Rock Mechanics & Mining Geotechnics.

Brazil The Brazilian NG (CBMR–Brazilian Committee on Rock Mechanics) belongs to the Brazilian Society for Soil Mechanics and Geotechnical Engineering (ABMS), the largest geotechnical society in South America. The CBMR produced, at the end of 2008, a CD with all the Proceedings of the Brazilian Symposia on Rock Mechanics up to 2008 and is organising the 5th Brazilian Symposium on Rock Mechanics which will be integrated to COBRAMSEG 2010, the 15th Brazilian Conference on Soil Mechanics and Geotechnical Engineering, which commemorates the 60th anniversary of ABMS and also incorporates the 4th Brazilian Young Geotechnical Conference and the 5th Luso-Brazilian Geotechnical Conference. This large conference is to be held in Gramado from 18th to 22nd of August, 2010.

Chile No activity is reported from the NG Chile. A conference, Slope Stability 2009, devoted mainly to rock slopes and organised by the Universidad de los Andes & CSIRO (Australia), was held in Santiago from 9th to 11th November, 2009.

Colombia The Colombian NG (Colombian Geotechnical Society–SCG) organized a one-day free Seminar on Mining and Environment on October 30th, 2009; a 2-day Seminar on Rockfill Dams from 12th to 13th of November, 2009 and a 4-day internal course on Slope Stability for the Colombian Geological Institute (INGEOMINAS) from 17th to 20th November, 2009. The SCG will host the ISRM Interim Board Meeting on 8th February, 2010, followed the next day by an ISRM International Seminar on “Latest Developments in Rock Engineering”, with ten lectures from the ISRM Board Members. The Board Meeting and the International Seminar will take place at the Colombian National University in Bogota. SCG is also organizing, from 14th to 17th September, 2010 in Manizales, a city in the Colombian Coffee Belt, the XIII Colombian Geotechnical Congress and the VIII Colombian Geotechnical Seminar, this last one on Mining Geotechnics.

Paraguay The Paraguayan NG (SPG), which has a Rock Mechanics Vice-Presidency, continued the Lecture Series on the Weak Rocks and Indurated Soils of Paraguay.

Peru The Peruvian NG is organising the VII South American Symposium on Rock Mechanics, to be held in 2010 as a Regional ISRM event.

Venezuela The Venezuelan NG (SVG) organised the 50th SVDG Anniversary Conference in Honour of Gustavo Luis Perez Guerra, from 7th to 9th November, 2008 in Caracas, which included some papers on rock mechanics.

3. General Comments

Most ISRM NG groups in South America are merged with the National Geotechnical Societies and only Brasil has a Rock Mechanics Committee (as well as a Tunnelling Committee) and Paraguay a Rock Mechanics Vice-Presidency. This does not allow one to easily separate rock mechanics activities from general geotechnical activities. However, independent NG groups have been recently created in Chile and Perú, two countries with intense mining industry.

A Tribute to Academician Professor Eugeny I. Shemyakin

John A Hudson, UK (john.a.hudson@gmail.com)



Prof. Eugeny I. Shemyakin

It is with great sadness that we learnt that Academician Prof. Eugeny I. Shemyakin, a former ISRM Vice-President at Large (1989-1991), passed away in Moscow, Russia, on 17 February 2009 at the age of 79.

E. I. Shemyakin graduated from High School with the Gold Medal Award. He became a student and then a graduate student of the Mechanical-Mathematical Faculty of the Leningrad State University. In 1955, he defended his Candidate Thesis on wave propagation in imperfectly elastic media. His doctoral thesis was devoted to wave propagation during underwater and underground explosions.

Following this PhD in physics and mathematics at the Leningrad State University, he then joined the Institute of Chemical Physics, of the USSR Academy of Sciences, in Moscow. In 1960, he moved to the Siberian Branch of the USSR Academy of Sciences, in Novosibirsk, where he was first Head of the Rock Mechanics Laboratory of the Institute of Theoretical and Applied Mechanics, and then Director of the Mining Institute and Vice-President of the Siberian Branch. Concurrently, he worked at the Novosibirsk State University (Chair of Elasticity).

In 1987, he returned to Moscow, as Chairman of the Supreme State Committee of Attestation, Main Consultant for the Institute of Dynamics of Geospheres, of the Russian Academy of Sciences, and Professor at the Moscow State University (Chair of Wave and Gas Dynamics).

Professor Shemyakin was a Member of the USSR Academy of Sciences, a Member of the Royal Swedish Society of Engineers (IVA), and a Member of the Czechoslovakian Academy of Sciences. He was a State Prize laureate, holder of the Badge of Honour, Friendship of People and other decorations and medals awarded both in Russia and in foreign countries.

He dedicated his scientific activities to studying plastic deformations and failure of solids, developing mathematical models of the consequences of explosions in order to calculate the seismic effect and the brittle failure of solids as applied to problems in mining. One of the striking examples of these investigations is his 1995 hypothesis on the origin of diamond-bearing kimberlite pipes. An analysis of diamond deposits and of the existing explanations of their origination has led to a fundamentally new hypothesis concerning the origin of kimberlite pipes as caused by large meteorites, their fall, impact, and high-speed penetration into the Earth. These studies which represented the accumulated experience, ideas, and methods of mechanics have generated a new class of problems on the interaction of the Earth and extra-terrestrial bodies.

Also, and while at the Institute of Mining, Siberian Branch, Russian Academy of Sciences, Professor Shemyakin created a scientific school in the field of mechanics of solids, rocks, and loose materials. His fellow scientists directed their studies to an analysis of the complex loading of plastic bodies, the construction of mathematical models and the solution to problems concerning the deformation of rocks and loose media, as well as the investigation of newly formed deformational structures and the effects of the Earth's rock masses under the action of tidal forces.

Along with these studies, his applied work on rock pressure monitoring, plastic and powder material processing, as well as control of loose material flow in ore chutes have been recognized in Russia and abroad.

The scientific results obtained by Professor Shemyakin are published in six monographs and more than 250 papers.

A Tribute to Dr Martin Johannes Pretorius

Nielen van der Merwe, S. Africa (nielen@stablestrata.com)



Dr Martin Johannes Pretorius

Martin Pretorius, ISRM Vice-President for Africa 2003 – 2007, passed away on Sunday 29 November 2009 at the age of 53 after a brave and long battle with leukemia. Like the long distances he was so fond of running, he did not give up until it was over.

Martin's career was spent on the deep gold mines in South Africa, in capacities ranging from production to rock engineering and technical advisor. He found the time to complete a Master's degree in Engineering and a PhD, both part time, working nights and weekends.

From a work perspective, he was hard working, intelligent and diligent. When he was appointed as technical advisor at the Harmony Gold Mining group, his instruction by the then CEO, Bernard Swanepoel, summarised Martin's attitude and abilities by this very simple brief: "Teach the guys on the mines to think like you do". That was all — that was all that was necessary.

He served the technical community through his duty on the Council of the South African National Institute for Rock Engineering for several years, including a period as President and then as ISRM

Vice-President for Africa.

Upon being notified of Martin's passing away, his colleagues on the previous ISRM Board who could be reached had this to say:

"...really sad news, and doubly so since he was a close colleague of us all..."

John A Hudson

"...I found him to be a man of depth and integrity..."

John St George

"...so many times his good judgment had strong importance to enlarge my own thoughts..."

Eda de Quadros

"...a very nice and friendly person, and too young to leave us..."

Luis Lamas

The words 'nice', 'friendly' and 'integrity' describe the person Martin was. Those who had the privilege of knowing him, also know that he quietly set the example: always calm, thoughtful, mindful of the needs and the feelings of others. He never had to combat negative concepts like hate, anger and revenge – those simply did not exist in him.

In Martin's own words:

"One of the things I resolved was not to ask why something like this had to happen to me, however difficult it was at times. I am not even sure that one would ever come to a satisfactory answer after hours of moping and wasting time! Life is simply too short to waste time and energy on such issues. I will rather spend my time and energy making life better for those close to me and those with whom I come into contact."

At this time, our thoughts are with Martin's wife, Christa, and their children Stefan, Martin and Christelle.

Rest in peace, dear friend, you have made life better for all of us who were touched by your gentleness.

*Nielen van der Merwe
ISRM President, 2003-2007*

Introduction to the ISRM Commissions

John A Hudson, UK, ISRM President (john.a.hudson@gmail.com)

The operation of the ISRM consists of two main elements:

1. Administrative matters, i.e. the running of the Society through the ISRM Vice-Presidents and the ISRM Secretariat, involving dealing with members' queries, updating the website, organisation of the Board and Council meetings each year, preparing the electronic News-letters, and a host of other tasks; and
2. Running the ISRM Commissions. These Commissions are also an important part of the ISRM's operation because they enable new developments to be made and, through the publications of the Commissions, for the information to be disseminated to the ISRM members and the wider public.

The ISRM Commissions are organised with a Commission President who is supported by Commission members, typically 5 to 10 such members. Each Commission has a task concentrating on a specific research objective or collation of information about a particular subject. An example is the Testing Methods Commission (President, Resat Ulusay, Turkey) which produces our Suggested Methods providing guidance on testing rock in the laboratory and in the field.

The life of each of these ISRM Commissions is four years, synchronised with the tenure of each ISRM President, so we are now in the 2007-2011 period. In a few cases, a Commission's life is continued through two or more such 4-yearly periods, as is the case with the Testing Methods Commission, but in most cases the Commission's life is four years.

This means that each of the Commissions must have a conscientious Commission President and be well structured with appropriate milestones, so that the Commission will definitely produce a worthwhile product at the end of its lifetime. There is no value in establishing ISRM Commissions if they do not produce anything worthwhile.

Accordingly, and when establishing the Commissions during my 2007-2011 tenure, I asked all the current Commission Presidents to set out their objectives and milestones (and associated yearly presentations), and to promise me that they will do their best to achieve the objectives.

Currently, there are nine ISRM Commissions as follows (in alphabetical order):

1. Commission on the Application of Geophysics to Rock Engineering
President: Toshifumi Matsuoka (Japan)
Purpose: To organise international Workshops and create a rock physics database website
2. Commission on Education
President: Cai Meifeng (China)
Purpose: To organise educational events
3. Commission on Mine Closure
President: Christophe Didier (France)
Purpose: To produce a report and book about the state-of-the art with some well documented 'case studies'
4. Commission on the Preservation of Ancient Sites
President: Li Zuixiong (China)
Purpose: To encourage exchange of ideas, teaching, research and advancement of knowledge in this field
5. Commission on Radioactive Waste Disposal
President: Wang Ju (China)
Purpose: To provide a network for information exchange and to organise workshop/conferences
6. Commission on Rock Dynamics
President: Zhou Yingxin (Singapore)
Purpose: To arrange meetings and to co-ordinate rock dynamics research activities within the ISRM community, produce reports and guidelines
7. Commission on Rock Engineering Design Methodology
President: Feng Xia-Ting (China)
Purpose: To produce a report on modern rock engineering design with an auditing capability
8. Commission on Rock Spalling
President: Mark Diederichs (Canada)
Purpose: To bring together the disparate information on rock spalling and produce an associated report
9. Commission on Testing Methods
President: Resat Ulusay (Turkey)
Purpose: To prepare the ISRM Suggested Methods

Where appropriate the work to date and the intentions of these ISRM Commissions are summarised by the Commission Presidents in the reports in the following pages of this News Journal, pages 43-57.

Toshifumi Matsuoka, Japan (matsuoka@earth.kumst.kyoto-u.ac.jp)

1. Introduction

Geophysical surveys are key tools for investigating the sub-surface rock properties and one of the main objectives of the ISRM Commission on the Application of Geophysics to Rock Engineering is formulating a Suggested Method which becomes a standard way of applying geophysical tools. Also, the Commission is introducing newly developed and useful geophysical approaches to rock mechanics.

The Commission consists of the following 15 members: Prof. T. Matsuoka (Commission Chair), Prof. E. Brueckl, Prof. Xu Chang, Dr. C. Cosma, Prof. A. Ghazvinian, Prof. P. Hatherly, Dr. Jung-Ho Kim, Prof. S. King, Dr. B. Lehmann, Dr. S. Lüth, Prof. C. J. de Pater, Prof. L. J. Pyrak-Nolte, Dr. E. Sellers, Dr. S. Tanaka and Prof. P. Young.

2. Publication of Workshop papers

As we have reported earlier, the Commission held the 8th International Workshop on the Application of Geophysics to Rock Engineering at the Westin San Francisco, Market Street, San Francisco, U.S.A. on 29th June 2008 in conjunction with the ARMA San Francisco 2008 Symposium. At the Workshop 12 papers were presented and these were followed by discussion.

After the Workshop, the Commission decided to publishing selected papers in an appropriate Journal, which was a Special Issue of the International Journal of the JCRM (the Japanese Committee for Rock Mechanics). As a Society technical journal, the JCRM was established in 1964 by researchers and engineers who were the members of the Japan Society of Civil Engineers (JSCE), the Mining and Metallurgical Institute of Japan (currently, the Mining and Materials Processing Institute of Japan (MMIJ)), the Japanese Society of Soil Mechanics and Foundation Engineering (currently, the Japanese Geotechnical Society (JGS)) and the Society of Materials Science, Japan (JSMS) to foster collaboration between the JCRM and ISRM in developing innovative solutions to rock mechanics and rock engineering problems.

The Commission selected and reviewed the following seven papers which were published in 2008, Vol. 4, No. 2, as a “Special Issue on Geophysics”

Application of MEMS accelerometer to geophysics; Takao AIZAWA, Toshinori KIMURA, Toshifumi MATSUOKA, Tetsuya TAKEDA and Youichi ASANO, 33-36.

Poroelectric modelling of fracture-seismic wave interaction, Seiji NAKAGAWA, 37-46.

Seismic prediction ahead of a tunnel face - Modelling, field surveys, geotechnical interpretation, T Stefan LÜTH, Aissa J. RECHLIN, Rüdiger GIESE, Jannis TZAVARAS, Kolja GROSS, Stefan BUSKE, Stefan JETSCHNY, Denise DE NIL and Thomas BOHLEN, 47-51.

Rock physics model for interpreting elastic properties of soft sedimentary rocks, Toru TAKAHASHI and Soichi TANAKA, 53-59.

Numerical simulation of solid particle behaviour in fluid flow by using a numerical method coupling technique, Satoshi OHTSUKI and Toshifumi MATSUOKA, 61-69.

Seismoelectric measurements in rock samples and borehole models, Zhenya ZHU and M. Nafi TOKSÖZ, 71-77.

The effect of fabric-controlled layering on compressional and shear wave propagation in carbonate rock, Weiwei LI, Christopher PETROVITCH, and Laura J. PYRAK-NOLTE, 79-85.

The journal is a WEB journal and all manuscripts can be downloaded from the following site:

http://www.rocknet-japan.org/journal/journal_top.html

3. Workshop in Hong Kong 2009 and New Delhi 2010

The Commission had planned to organise the 9th International Workshop on 17 May 2009 in conjunction with the SINROCK2009 meeting. Unfortunately, however, this Workshop was cancelled as a precaution because of the swine flu. Also, many participants from Japan, China, and Korea were thus unable to attend the SINROCK2009 meeting and so there would not have been enough papers for the Workshop.

Based on this 2009 cancellation, the Commission is anticipating that the next Workshop will be held in New Delhi, India, in 2010 in association with the 6th Asian Rock Mechanics Symposium, ARMS6.

ISRM Education Commission: 2009 Report

Meifeng Cai, China (caimeifeng@ustb.edu.cn)

The main products of the ISRM Commission on Education in 2009 were organising the 2009 ISRM China Lecture Tour and coverage of the Proceedings of the International Young Scholars' Symposium on Rock Mechanics in EI and ISTP databases.

1. 2009 ISRM China Lecture Tour

The lectures, which immediately preceded the SINOROCK2009 Symposium covered the principles of rock mechanics and the process of rock characterisation, modelling and design for rock engineering, based on the books by John A Hudson and John P Harrison —“Engineering Rock Mechanics 1: An Introduction to the Principles” and “Engineering Rock Mechanics 2: Illustrative Worked Examples”.

The lectures took place from 9-15 May, 2009, at

- Beijing: USTB (University of Science and Technology Beijing); CUMT (China University of Mining and Technology); and Tsinghua University
- Nanjing: Hohai University
- Wuhan: WHRSM (Wuhan Research Institute of Soil and Rock Mechanics) and
- Hong Kong: HKU (Hong Kong University).

The lecturers and their topics were as follows:

Dr John P Harrison, Imperial College, UK

Lecture 1: An integrated approach to engineering rock mechanics

Lecture 2: The role of progressive breakdown in the behaviour of intact rock

Professor John A Hudson, ISRM President, Imperial College, UK

Lecture 1: Understanding rock stress: its nature, measurement and variations

Lecture 2: Rock mechanics interactions and rock engineering systems

Lecture 3: How to write a paper for publication in an international journal (with John Harrison)

Dr Tony Meyers, ISRM Vice-President for Australasia

Lecture 1: Importance and characterisation of rock fractures

Lecture 2: Challenges faced when designing large slopes in rock

Professor Resat Ulusay, President of the ISRM Commission on Testing Methods

Lecture 1: Rock properties and their role in rock characterisation, modelling and design

Lecture 2: The ISRM ‘Blue Book’ containing all the ISRM Suggested Methods

The Lecture Tour received significant support from the CSRME, relevant Universities and Institutes, for which the ISRM is extremely grateful, and was warmly appreciated by the Chinese community of rock mechanics and listeners.

The number of lectures in terms of the total audience was about 3000 person-lectures

2. Inclusion of the Proceedings of the International Young Scholars' Symposium on Rock Mechanics in the EI and ISTP databases

The International Young Scholars' Symposium on Rock Mechanics was held in Beijing on 28th April-1st May 2008. The Proceedings of the Symposium titled “Boundaries of Rock Mechanics – Recent advances and Challenges for the 21st Century” includes 182 papers which have all been included in the databases of both EI (the Engineering Index) and ISTP (Index to Scientific & Technical Proceedings).

This demonstrates the high quality and success of the Symposium which has created extensive and beneficial repercussions throughout the Chinese rock mechanics community.



Lecturers with Meifeng Cai at the University of Science and Technology, Beijing

ISRM Preservation of Ancient Sites Commission: 2009 Report

Li Zuixiong, China (lizuixiong@yahoo.com.cn)

This report covers the 2008-2009 period and includes a brief retrospection plus the main tasks accomplished, including organisation of the 2008 Symposium, publication of the proceedings and other items.

1. Brief retrospection

The ISRM Commission on the Preservation of Ancient Sites was formally approved by the ISRM authority last year.

The terms of reference of the Commission are as follows:

- Collection of major case histories of preservation from all over the world;
- Hosting international symposia;
- Preparing an inventory of ancient sites;
- Listing of publications in the international literature;
- Publication/publicity;
- Fostering the organisation of training courses;
- Holding Workshops and special sessions; and
- Establishing/maintaining a website.

The first Commission meeting was held in association with the 2008 ISRM International Symposium i.e., the 5th ARMS held in Tehran Iran, in November 2008. The main topics discussed were: Commission membership; sharing out the work; and cooperation.



John A Hudson, ISRM President, congratulating Xian Hui, the Vice-Governor of Gansu Province, China, on the highly successful ISRM Regional Conference.

2. Main tasks accomplished

Organisation of the International Symposium on the Conservation of Ancient Sites 2008 (ISCAS-2008), a 2008 ISRM-Sponsored Regional Symposium.

This Symposium was also sponsored by the Chinese Society for Rock Mechanics and Engineering (CSRME), the Dunhuang Academy of China and the Lanzhou University, and was held in Dunhuang — a famous World Cultural Heritage site, on 22-24 September 2008.

The Honorary President of the Symposium was Prof. Qian Qihu; the President was Prof. Li Zuixiong; and the Vice-Presidents were Wang Xudong, C. Tanimoto and Chen Wenwu. More than 170 participants from different countries attended the Symposium.

The Symposium was highlighted by the lectures from Prof. J.A. Hudson, Prof. C. Fairhurst, Prof. M. Coli, Dr. J. D. Rodrigues, Prof. Qian Qihu, Prof. Wang Sijing, Prof. Li Zuixiong, Prof. Wang Xudong, *et al.*

Just as Prof. J. A. Hudson, President of the ISRM said, “I rank this as one of the best Symposia that I have ever attended”, and “I believe that for the ISRM this Symposium represents a watershed from which many good things will flow”. So, we have achieved fruitful results actually.



Li Zuixiong, the Commission President, delivering the opening speech at ISCAS-2008.

ISRM Preservation of Ancient Sites Commission (cont.)

Publications

- Proceedings of the International Symposium on the Conservation of Ancient Sites 2008 (ISCAS-2008) – the 2008 ISRM-Sponsored Regional Symposium – containing all the 79 papers, with an important preface written by Prof. J.A. Hudson, President ISRM, was published by Science Press of China for international communication.
- A Special Issue of the News Journal of the Chinese Society for Rock Mechanics and Engineering on the topics of ISCAS-2008 and relevant affairs, mostly with English abstracts, was published for reference.
- Technical articles relating to the conservation of ancient monuments and sites, the first authors being Profs. J.A. Hudson, Li Zuixiong, A. Ghazvinian, M. Coli, C.I. Lee, C. Fairhurst and J.D. Rodrigues, have been published in last year's ISRM News Journal, Vol. 11, December 2008.

Other items

- Maintaining the Commission's correspondence files, drafts of reports, and other working documents complete and in good order.
- Issuing the letters of appointment to all Commission members, etc.

3. The items in progress

- Collection of major case studies of preservation from all over the world
- Compiling an inventory of ancient sites
- Listing of publications in the international community
- Publication and publicity
- Fostering the organisation of training courses
- Hosting workshops and special sessions
- Establishing and maintaining a website.

Acknowledgement

Sincere thanks are due to Prof. J.A. Hudson, President of the ISRM, and Dr. L. Lamas, Secretary-General of the ISRM, for their kind help and consideration in forwarding the objectives of the Commission.



L to r: Xia-Ting Feng (VP ISRM), Wang Xudong (VP Dunhuang Academy of China), Fan Jinshi (President, Dunhuang Academy of China), John A. Hudson (President ISRM), Li Zuixiong (President ISRM Commission on the Preservation of Ancient Sites) and Fu Bingjun (Adviser, NG China ISRM)

ISRM Radioactive Waste Disposal Commission: 2009 Report

Wang Ju, China (radwaste@public.bta.net.cn)

The first meeting of the Commission on Radioactive Waste Disposal (CRWD) of the ISRM was held on 18 May 2009 in the University of Hong Kong, China, in conjunction with the SINOROCK2009 Symposium. 12 of the 18 Commission Members were either present or represented. The President of the CRWD, Prof. Ju Wang, chaired the meeting covering the following topics:

- Introduction to the Commission on Radioactive Waste Disposal (CRWD) of the ISRM, including the main objectives of the CRWD, major activities and the Commission members
- 2008 Annual Report of the CRWD
- Discussion on future activities.

1. The Objectives of the Commission

It was agreed that the objectives of the Commission should be:

1. To establish a platform for scientific and information exchange of rock mechanics in the field of radioactive waste disposal
2. To organise workshops/conferences related to radioactive waste disposal, independently or within the context of an ISRM conference
3. To establish a network for the rock mechanics scientists working on radioactive waste disposal
4. To provide scientific advice to relevant organisations who are working on radioactive waste disposal
5. To explore scientific collaboration with sister societies and relevant organisations, such as IAEG, etc.

2. 2008 Annual Report of the Commission

The annual report of the Commission was presented at the meeting covering:

- the establishment of the Commission,
- the Second National Conference on Underground Waste Disposal, 24-27 September 2008, Dunhuang, China, at which 150 participants from 50 organizations attended, including the President of ISRM, John A Hudson. The five sessions included: site selection, site characterization, and safety assessment; rock mechanics; engineered barriers; waste forms and radionuclide migration; disposal of industrial waste and

carbon dioxide. There was also a field trip to Beishan, Gansu Province, the potential site for China's high level radioactive waste disposal.

- For the SINOROCK2009 Symposium, Dr. Wang Ju presented a keynote lecture, and there were two sessions on radioactive waste disposal. 26 papers were related to radioactive waste disposal.

3. Future activities

The following activities were agreed:

- International Workshop on Radioactive Waste Disposal for 17 October 2011, prior to the ISRM2011 (12th International Congress on Rock Mechanics), which will be held in Beijing, China.
- The Commission plans to prepare an ISRM-Suggested Method for borehole televiwer measurement, in collaboration with the Commission on Testing Methods.
- The Commission also plans to prepare a report prior to the 2011 Workshop which will summarise the progress in radioactive waste disposal programmes in several nuclear countries.

Participants at the first meeting of the CRWD were Ju Wang, George Tham, John A Hudson, Qihu Qian, Rolf Christiansson, Abbas Majdi, Stefan Heusermann, Yuemiao Liu, Claus Erichsen, Eda Freitas de Quadros, Quanhong Feng and Zihua Zong.



The 1st Commission meeting held on May 18, 2009, at The University of Hong Kong in association with SINOROCK2009

ISRM Rock Dynamics Commission: 2009 Report

Yingxin Zhou, Singapore (zyingxin@dsta.gov.sg)

1. Introduction

The ISRM Commission on Rock Dynamics was approved by the ISRM President in Jan 2008, with Dr Yingxin Zhou of the Singapore NG as the Commission President. The Commission members are: Omer Aydan, Steve Brandon, Ezio Cadoni, Ming Cai, Conrad Felice, Giovanni Grasselli, Haibo Li, Xibing Li, Guowei Ma, Bibhu Mohanty, Chong Chiang Seah, Chun'an Tang, Kaiwen Xia, Jian Zhao, and Yingxin Zhou

The terms of reference for the ISRM Commission on Rock Dynamics include:

- Provide a forum for the sharing and exchange of knowledge in rock dynamics research and engineering applications. This includes organising Commission meetings, as well as Workshops, Seminars and Short Courses in connection with ISRM-supported events.
- Co-ordinate rock dynamics research activities within the ISRM community, as well as with other research and professional organisations (e.g. the International Society of Explosives Engineers).
- Produce reports and guidelines on the study and engineering applications of rock dynamics covering fundamental theories, dynamic properties of rock and rock mass, testing methods, tunnel response, and support design.

The short-term goal is to produce a Document on Suggested Methods for Rock Dynamic Testing. The long-term goal is to produce a Guideline on Rock Dynamic Response and Support Design.

2. Work Plan and Timetable

The work plan and schedule of the Commission in the first three years are:

- Year 1 – Appointment of Commission members, preparation and communication of work plan and work assignment, and initiation of Commission work; Literature review on rock dynamic testing; Compilation of rock dynamics properties.
- Year 2-3 – Preparation of Suggested Methods on Rock Dynamics Testing.

3. Commission Activities for 2009: Workshop on Rock Dynamics

The main activity of the Commission for 2009 was the Workshop on Rock Dynamics held on 17-18 June 2009 at the Swiss Federal Institute of Technology Lausanne (EPFL), hosted by Jian Zhao, Director of the Rock Mechanics Laboratory (EPFL).

The Workshop brought together 35 participants from 13 countries for two days of very engaging presentations and discussions. John Hudson, President of the ISRM, attended and gave some opening remarks at the beginning of the Workshop. The following is the list of presentations made at the Workshop.

- An overview of the state-of-the-art research progress in rock dynamics, Jian Zhao
- Measurement of dynamic tensile strength in rock by means of explosive-driven Hopkinson bar method, Bibhu Mohanty
- Hopkinson pressure bar tests of rocks: advancements in experimental techniques and applications to rock compression, tension and fracture, Kaiwen Xia



Attendees at the June 2009 ISRM Rock Dynamics Workshop held at the EPFL in Lausanne, Switzerland

- Modified Hopkinson bar technologies applied to the high strain rate of rocks, Ezio Cadini, Carlo Albertini
- Mathematical approaches in fracture dynamics, Morosov Nikita, Yury Petrov, Vladimir Bratov
- Characterisation of the Iddefjord granite for penetration studies, Chong Chiang Seah
- Failure mechanism of brittle rock under dynamic load, Guowei Ma
- Earthquakes as a rock dynamic problem and their effects on rock engineering structures, Omer Aydan, Yoshimi Ohta, Mitsuo Daido
- Constraining paleoseismic PGA using numerical analysis of structural failures in historic masonry structures, Yossef Hatzor
- Spalling in extreme ground motion and evidence from the 2008 Wenchuan earthquake, Chun'an Tang
- Rock tests on large diameter SHPB with special shape striker, Xibing Li, Zilong Zhou
- Stability analysis using discontinuous dynamic computations, Gen-hua Shi
- Necessity of developing standard procedures and benchmarks for the validation of rock dynamics numerical codes, Giovanni Graselli
- In-situ experimental study and numerical analysis on the propagation of blasting seismic wave in large tunnel group, Xinping Li
- Explosion loading and tunnel response, Yingxin Zhou
- Investigation of stress-wave induced fractures in explosively-loaded rock samples for calibration of numerical models, Bibhu Mohanty.

4. Suggested Methods for Dynamic Rock Testing

The Commission also had discussions with the Commission on Testing Methods on procedures for drafting and publication of Suggested Methods for Rock Dynamics Testing. At the Workshop in June 2009, the Commission decided to work on two Suggested Methods for Rock Dynamic Testing. They are “Dynamic Uniaxial Compression Tests” and “Dynamic Tension of Rocks Using the Brazilian Test”. A third method on “Dynamic Fracture Toughness Test” is also under consideration. Work plans for drafting these test methods

have been prepared and circulated to members of the Commission.

5. Participants at the Rock Dynamics Workshop

ALBERTINI Carlo, Italy
 AYDAN Omer, Tokai University, Japan
 BRATOV Vladimir, RAS Institute of Problems of Mechanical Engineering, Russia
 CADINI Ezio, University of Applied Sciences of South Switzerland, Switzerland
 CARRANZA-TORRES Carlos, University of Minnesota Duluth, USA
 CONSTANTIN Plytas, O.T.M. S.A., Greece
 DAIDO Mitsuo, Tokai University, Japan
 FELICE Conrad, University of Washington, USA
 GOEL RK, Central Mining Research Institute, India
 GRASSELLI Giovanni, University of Toronto, Canada
 HATZOR Yossef, Ben-Gurion University of the Negev, Israel
 HUDSON John, Imperial College London, UK (ISRM President)
 JEON Seokwon, Seoul National University, Korea
 KHLUDNEV Alexandr, RAS Lavrent'ev Institute of Hydrodynamics, Russia
 LI Xinping, Wuhan University of Technology, China
 LIM Shiyi, Defence Science & Technology Agency, Singapore
 MA Guowei, Nanyang Technological University, Singapore
 MOHANTY Bibhu, University of Toronto, Canada
 MOROZOV Nikita, St. Petersburg State University, Russia
 PETROV Yury, St. Petersburg State University, Russia
 RESENDE Ricardo, LNEC (National Laboratory for Civil Engineering), Portugal
 SEAH Chong Chiang, Defence Science & Technology Agency, Singapore
 SHI Gen-Hua, DDA Company, USA
 TANG Chun'an, Dalian University of Technology, China
 XIA Kaiwen, University of Toronto, Canada
 XU Tao, Dalian University, China (Visiting Scientist at EPFL LMR)
 ZHAO Jian, École Polytechnique Fédérale de Lausanne, LMR, Switzerland
 ZHOU Yingxin, Defence Science & Technology Agency, Singapore (ISRM-CRD President)
 Zhou Zilong, Central-South University, China

and PhD Students

CASTRO-CAICEDO Alvaro, Universidad Politécnica de Madrid, Spain
 KAZERANI Tohid, Ecole Polytechnique Fédérale de Lausanne, LMR, Switzerland
 NEMATI Navid, Ecole Polytechnique Fédérale de Lausanne, LMR, Switzerland
 SHIRNEN Alexander, Ecole Polytechnique Fédérale de Lausanne, LMR, Switzerland
 ZHAO Gao-Feng, Ecole Polytechnique Fédérale de Lausanne, LMR, Switzerland
 ZHU Jianbo, Ecole Polytechnique Fédérale de Lausanne, LMR, Switzerland

Xia-Ting Feng, China (xtfeng@whrsm.ac.cn), and John A Hudson, UK (john.a.hudson@gmail.com)

1. Introduction

The purpose of the Commission is to develop a manual for rock engineering design methods using experience from the large projects in China. Thus, the main product of the Commission is to create a design manual in book form outlining:

- methods of design for underground structures in rock masses;
- the types of information required to support such rock engineering design;
- methods for auditing design procedures, both concurrently with the design process and subsequently; and
- illustrative case examples of design and auditing based on major projects in China.

The work is being undertaken in the period 2007-2011 via an Overseeing Committee, Task Force Committee and the ISRM Commission. A Working Group meeting of the Task Force Committee headed by Profs Feng and Hudson was held on 19 September, 2008 in Beijing, in order to progress the “Modern Design Methodology for Rock Engineering Projects” mission initiated by the CSMRE and ISRM. Progress achieved from the meeting was as follows.

2. The book structure

The book has been structured in four parts for clarity.

- Part 1A: Background text and figures on the nature of rock engineering design, related flowcharts, identifying the information needed and the concept of technical auditing.
- Part 1B: A series of illustrative case examples of rock engineering design covering slopes and underground excavations, including complicated slopes - Fengshuxia iron mine slope and Nuozhadu hydraulic slope, Jinping II underground powerhouse, Jinping II hydraulic tunnels at 1800-2500 m depth, and one coal mine entry.
- Part 2A: An explanation of the Protocol Sheets used to guide and record the decisions made and information obtained at the various stages of the site investigation, modelling and design.
- Part 2B: An example set of completed Protocol Sheets for the design of the underground

powerhouse for the JinPing II hydroelectric project in China.

The complete book is being compiled with assistance of the Overseeing Committee and the Task Force Committee and a first draft is being reviewed by the ISRM Commission on Rock Engineering Design Methodology during December 2009 and January 2010.

The draft for Parts IA and IIA was finished before November 2008, and the draft for Parts IA is being revised according to the following:

- Comments taken at the ISRM Council meeting in Tehran, 23 November 2008
- AFTES Guidelines for Characterisation for Rock Masses Useful for the Design and the Construction of Underground Structures, Version 1, June 2003, sent by Dr. Thierry You, President of ISRM National Group for France
- Comments of two reviewers for the paper on “Specifying the information required for rock mechanics modelling and rock engineering design”
- Application progress of the Chinese rock classification system for rock engineering design used in China
- Z. T. Bieniawski’s paper: “Reflections on new horizons In rock mechanics design: theory, education and practice”, Proceedings of the ISRM International Symposium 2008 - 5th Asian Rock Mechanics Symposium, p 37-50, 2008

3. Case examples

Based on the generalised ideas of the rock engineering design methodology, the design methodology is expanded accordingly to satisfy requirements of the different types of rock engineering projects, e.g. an underground cavern group, high slopes, mine entries, etc. Case examples will be included to illustrate the applications.

Case 1: Design of a large underground powerhouse

For the design of a large underground powerhouse cavern group, under complicated geological conditions, a methodology of dynamic feedback analysis and design optimisation is presented using data updating and intelligent methods. To understand the effect of inter-dynamical geologi-

cal processes and processes relating to the current geostress character of a tectonic region, a new non-linear back analysis method for the initial geostress field is given, which integrates the rock denudation simulation, numerical elasto-plastic calculation and neural network inversion. The method takes the geology structure order process into account by elasto-plastic calculation and simulates the rock denudation process by surface excavation. Since the bench construction of large underground caverns has the features of trenching layer by layer from top to bottom, these features were considered in the dynamic feedback analysis and design optimisation of large underground caverns. With monitoring data, the method forms a closed-loop feedback system by integrating the recent progress in rock mechanics, 2-D and 3-D numerical simulation, 3-D visualisation techniques, and artificial intelligence algorithms.

The dynamic design of the Jinping II hydraulic underground powerhouse is taken as one illustrative case example of underground rock engineering projects. Before the construction, the following tasks are undertaken for the Jinping II underground powerhouse: 1) the geostress field is recognised using back analysis of the measured *in situ* stress data and tectonic action on the form of the mountain and deep valley; 2) the excavation procedure and support design are optimised; 3) the stability of the underground powerhouse after excavation layer by layer from top to bottom is estimated; and 4) the safe deformation classification is given for monitoring and warning.

And then, the following tasks are conducted for the construction of the underground powerhouse layer by layer:

- Once the excavation of a layer is completed, the monitored and observed mechanical responses of the cavern are compared to the calculated results, with respect to deformation, stresses, damage zones, force of anchor cables, rock bolts, and concrete lining. All kinds of information used for prediction, including mechanical models and parameters, are evaluated. The classification of the surrounding rock is checked according to the actual engineering geological condition revealed after the excavation. If a difference appears, the reasons for the difference are

investigated and the adjustment of the support design and the safe monitoring measures are recommended.

- All the information, including the monitored data, record of excavation procedure, and auditing results of the geological conditions, are input into a three dimensional geographic information system (GIS), which provides a platform for intelligent back analysis of parameters and deformation prediction of the caverns.
- The equivalent mechanical parameters of the surrounding rock are identified immediately by using integration of the three dimensional numerical analysis and searching in global space using Particle Swarm Optimization. By comparing the estimated geological conditions and revealed results during the construction, the geological conditions for the cavern for all lower excavation layers are estimated.
- With the identified parameters and the predicted geological conditions, the response of the cavern after excavation of the lower layer, including potential local failure, is analysed again. The deformation and failure mechanism of the surrounding rock is further analysed. Accordingly, the necessary safe monitoring measurement for controlling the stability of the caverns is checked and suggested. The deformation management standard for the lower excavation layers is checked or modified. The deformation behaviour, potential failure mode, and concentration degree of the secondary stress in the surrounding rock of the caverns after the excavation at lower layers are predicted.
- Based on the evaluation results of the stability of the caverns at the current layer and prediction of the mechanical performance of caverns after the lower layer excavation, the optimal global excavation procedure and support design and local strengthening reinforcement are recommended.
- The suggestions for excavation procedure and support design are fed back to the designer and contractor and carried out in subsequent construction.

With the methodology mentioned above, the excavation of the first five layers of the Jinping II

underground powerhouse was safely finished and the excavation of the last three layers was completed in September 2009.

2) Case 2: Design of Fengshuxia Iron Mine

Slope, China

Fengshuxia Open-Pit is situated in the southwest of Hainan Island, China, where the average annual rainfall is 2000 mm and the maximum sustained rainfall was 1123 mm in the past 50 years. Fengshuxia Open-pit was initially designed in 1972, with the 100 m high and 43° slope, and excavation started in 1980. Since the mid-1990s, landslides have occurred a few times in the south slope. The design had to be modified and some measures such as retaining walls and concrete pile reinforcements had been taken. However, the slope was still unstable, and a landslide occurred in 2000 and covered the ore body. Since then, the operator had to stop mining. In 2008, the operator decided to re-assess the stability of the slope and re-design the mine, which has been taken as an opportunity to demonstrate the new design methodology.

The objective of this work is to establish a new design that can mine out all the remaining ores under the prerequisites of ensuring the slope is stable during mining, satisfying environmental

regulations and operational requirements, and achieving maximised economical benefit. Based on the initial geological survey and analyses of historic landslides, the key issues of the south slope were identified as follows:

- 60 m thick entirely weathered rocks characterised by water-sensitive mechanical properties, and schistosity in the quartz-schist that lies below the entirely weathered rocks probably dominate the stability of the slope; and
- water plays an important role and so the hydraulic-mechanical coupling must be taken into account.

Accordingly, a flowchart for the design was developed. Initial surveys have been finished. 19 boreholes were drilled; BHTV, sonic logging and permeability measurements have been carried out. The majority of the field and indoor tests, and preliminary 2-D seepage calculations and LEM analyses have been completed.

The work of the Commission is still in the process of being fully developed – with the intention of having the draft Final Report presented at the time of the 2010 New Delhi ISRM International Meeting and the Final Report in book form presented at the ISRM Congress in Beijing in 2011.



Fengshuxia Iron Mine slope, China

ISRM Rock Spalling Commission: Report for 2009

Mark Diederichs, Canada (mdiederi@geol.queensu.ca)

The Commission on Rock Spall Prediction had its first meeting in May, 2009 at the SINOROCK Symposium in Hong Kong. The mandate of the Commission is to develop Suggested Methods for the determination, from laboratory tests, of key parameters for spalling prediction and to provide guidance for the determination of spalling potential for different rock types and rock mass characteristics. Secondary goals include the evaluation of predictive tools, for spalling around excavations, currently available to the practising engineer and to encourage further development of more sophisticated numerical techniques.

The current members of the Commission include:

- Mark Diederichs (President of Commission)
- Derek Martin (Co-President of Commission)
- Lars Jacobsson (Sweden)
- Bernie Gorski (Canada)
- Matti Hakala (Finland)
- Dick Stacey (South Africa)
- Ming Cai (Canada)
- Christer Andersson (Sweden)
- Marc Panet (France)
- Giovanni Grasselli (Canada)

The first definitive act of the Commission was to standardise terminology. A great deal of confusion has arisen from the adoption of non-unique acronyms and symbols for key testing thresholds such as damage initiation (s_{ci} , s_i , UCS*, etc) and critical crack damage stress (s_{cc} , s_{cd} , s_d , etc). The new standard terminology for parameters determined from uniaxial compression testing is as follows (all symbolic notation is replaced with capital letter acronyms):

UCS Unconfined Compressive Strength or ultimate rupture strength of a 45-55 mm diameter (NQ or NX core preferred) cylindrical sample 125-150 mm in length. This value should be viewed as a standard index and should not be adjusted to account for a field scale sample. Care should be taken when adjusting values from smaller core as there is uncertainty in the adjustment factor, particularly for large grained samples.

CD Crack Damage threshold or true yield strength of the rock sample. This threshold is determined from the onset of axial stress-strain non-linearity prior to peak stress (UCS) or is determined from the stress level when incremental volumetric strain reverses from contraction to expansion. This value (typically 70-90% of UCS) represents the upper bound for short term *in situ* strength. Unlike UCS, this yield

strength (critical damage density and crack coalescence) is relatively insensitive to test sample size. Standardisation of this measurement is required.

CI Damage initiation threshold for the rock sample. This threshold is marked by the onset of systematically increasing damage (cracks) with increasing applied stress (does not consider random cracking at the early stage of the test). This threshold can be determined by acoustic emission monitoring or by lateral strain measurements (onset of lateral or circumferential extension strain non-linearity). This threshold marks the lower bound for *in situ* rock strength, as well as the lower bound for long term strength, provided this limit is not exceeded during the excavation stress path. In uniaxial conditions, this stress limit is typically 35-50% of the UCS. Standardisation of this measurement is also required.

BTS Brazilian tensile strength as a measure of true tensile strength (T). The ratio of UCS to T is an indicator of spall potential. The 'true tensile strength' is also required for excavation scale spall simulation. BTS results, however, do not always correspond to T for many rock types. Work is required to understand this discrepancy.

As a second initiative of the Commission, a trial is currently underway to evaluate the reliability of CI, CD and UCS measurements. Five identical sets of 10 samples of grey granite from SKB (Forsmark) in Sweden have been sent to testing labs around the world. The labs have been asked to follow their current practices for both testing and for data analysis. The Commission will study these results as an aid in the development of the Suggested Methods for these test measurements. The reliability of BTS testing and the need for alternative testing practices will be examined through additional studies in the future.

Future work will include evaluation trials of different empirical and conventional numerical predictive tools for spalling and associated overbreak, using existing case histories.

Tunnelling or mining engineers and academics are encouraged to send information about useful case histories to Mark Diederichs (mdiederi@geol.queensu.ca).

Information should include: tunnel geometry, overbreak profile, *in situ* stress levels, rock type, rock mass quality and rock parameters including UCS, m , T or BTS, E, ν as well as CI and CD (if available). Any other information about the geology or operational issues is also welcome. These case histories will also be available to developers of new analysis techniques.

ISRM Testing Methods Commission: Report for 2009

Resat Ulusay, Turkey (resat@hacettepe.edu.tr)

The following activities were undertaken by the ISRM Commission on Testing Methods between the period September 12, 2008 and May 18, 2009.

1. The 2008 annual meeting of the Commission on Testing Methods was held on November 23, 2008, in Tehran, Iran, before the 5th Asian Rock Mechanics Symposium (ARMS5). It was clearly observed that in this year the interest in the work of the Commission considerably increased and, in addition to the Commission members, Prof. Dr. Shunsuke Sakuari (past President of ISRM), Dr. Claus Erichsen (ISRM Vice President-at-large), Prof. Dr. Alvaro Gonzales-Garcia (ISRM Vice-President for S. America), Prof. Dr. Sergio Fontoura (representative of Brazil), Prof. Dr. Wulf Schubert (representative of Austria), Dr. Don Banks (representative of USA), Prof. Dr. Ivan Vrkljan (EUROCK2009 Chairman) and his colleague from Croatia also participated in the Commission meeting.

2. During ARMS5, another meeting related to the activities of the Commission was also organised by the Co-ordinator and Secretary of the Working Group on the “Creep Test”, Prof. Dr. Omer Aydan and Prof. Dr. Takashi Ito, respectively, on 26 November, 2008. The Commission members Dr. Nuno Grossmann and Dr. Eda Freitas de Quadros, and Dr. Francois Malan (a member of this WG and ISRM Vice-President for Africa) and Dr. Don Banks (USA) participated in this meeting. Prof. Aydan informed the participants about the purpose, main objectives and current members of this WG, testing apparatus, and environmental considerations during creep testing, content of the document that will be prepared by the WG and time table. The participants agreed to contribute to the studies of this WG and it was decided to invite some other experts from different countries.

3. The possibility of the organisation of an ISRM sponsored symposium or specialized conference on “Rock Properties and Testing Methods” in Turkey by the Commission on Testing Methods with the support of ISRM Turkish National Group (TNG) was also discussed during the Tehran meeting. Because the proposed amendments to the ISRM By-law No. 5 had not been clarified

and not approved during the ISRM Council Meeting in Tehran, and the support on this issue from TNG has not been provided yet, this possibility was left to the future. However, contacts with the TNG on this organization will be continued.

4. The reviews of the Blue Book, published in three international geo-engineering journals, were requested from the editors. The review of the Blue Book was published in the journal “Environmental & Engineering Geosciences (Bulletin of AAEG)” in its February 2009 issue. The other reviews of the book will be published in the “Bulletin of Engineering Geology and the Environment (IAEG Bulletin)” and “International Journal of Rock Mechanics and Mining Sciences (IJRMMS)” in May 2009 and December 2009 issues, respectively. All these reviews are highly complimentary.

5. The Commission has decided that the establishment of a new Working Group (WG) on the “Abrasive Test” would be useful. For this purpose, the Commission considered that, since only the French standards exist for this test, an invitation to an expert from France as the WG Co-ordinator would be better. Although Dr. Robert J. Fowell, member of the Commission, tried to find an expert from France, the invited experts did not accept this mission due to their workload. Finally, Dr. Robert J. Fowell accepted to chair this WG which was officially established in April 2009.

Volunteers who would like to join and to contribute to this new WG, are kindly invited to contact Dr. Robert J. Fowell (University of Leeds, UK; e-mail: R.J.Fowell@leeds.ac.uk)

6. Co-operation between Turkish and Japanese groups via Resat Ulusay and Yuzo Obara (Commission member) for further studies on the needle penetration index test is still continuing. In addition, contact persons Dr. Dominique Ngan-Tillard from the geo-engineering section of Delft University, The Netherlands, and Dr. Yoshikazu Yamaguchi from the Hydraulic Engineering Research Group Public Works Research Institute, Japan were found. If a new WG on this index test

is decided to be established by the Commission, these two experts will be pleased to join the WG of the Commission.

Volunteers who are interested in this topic, please contact Prof. Resat Ulusay, President of the Commission: resat@hacettepe.edu.tr

7. Dr. Abbas Taheri and Prof. Dr. Kazuo Tani from Japan submitted a document entitled “Draft ISRM Suggested Method for Determining Rock Mass Strength and Deformability by In-situ Tri-axial Test” to the Commission for its evaluation. This was sent to three experts for reviewing. The comments of the reviewers on this document were discussed and evaluated by the Commission members in the Tehran Meeting. The members agreed with the comments of the reviewers that the results of the testing method should be verified by other means and deep borehole testing does not necessarily represent the rock mass conditions. Finally the Commission decided to encourage the authors to continue with this work and praise them for their creativity, but wait until they can compare their results with full scale *in situ* tests.

8. Based on the information received from the Co-ordinators, the activities of the new Working Groups (WG) responsible from the preparation of new and upgraded SMs are given below:

WG for SM on “Creep Test”

Co-ordinator: Prof. Dr. Omer Aydan, Japan (e-mail: aydan@scc.u-tokai.ac.jp)

Purpose: This WG intends to develop an ISRM Suggested Method for laboratory creep testing of rocks with consideration of available creep testing techniques used in the rock mechanics field as well as other disciplines of engineering. The preliminary purpose is to develop methods under laboratory conditions. Nevertheless, the same principles can be extended to in-situ creep tests with appropriate considerations of *in situ* conditions.

Current members: Prof. Dr. Takashi Ito (Japan, Secretary of the WG), Prof. Dr. M.A. Kwasniewski (Poland), Prof. Dr. Ugur Ozbay (USA),

Dr. François Malan (South Africa), Dr. T. Okuno (Shimizu Corporation, Japan), Prof. Dr. Abdurrahim Özgenoglu (Turkey).

WG for SM on “Standard Practice for Displacement Measurements Using Global Positioning System”

Co-ordinator: Prof. Dr. Norikazu Shimizu, Japan (e-mail: nshimizu@yamaguchi-u.ac.jp)

Activities: A Working Group composed of Japanese members investigated the error factors of GPS displacement measurements. These are keys for succeeding in applying this technology for monitoring rock movements. There are three main error factors of GPS, i.e. a) meteorological influence (atmospheric delay caused by changes in weather conditions), b) overhead obstacles (disturbance to the signals), and c) multi-path signal. The correction methods for improving the measurement accuracy was almost established through field measurement results. International members of the Commission will be called and invited for discussion for making a draft which will be started in 2009.

WG for SM on “Upgraded SM for Sonic Velocity Test”

Co-ordinator: Assoc. Prof. Dr. Adnan Aydin, USA (e-mail: aaydin@olemiss.edu)

All members of the WG have been active during this period. The WG has two independent sets of test results and the first draft of the SM. There are, however, problems with these tests and the draft of the SM is in need of significant improvement. A detailed analysis of this new information and developing guidelines will start with the aim of meeting the submission deadline in early 2010.

WG for “Upgraded SM for Determining Shear Strength Both in Field and Laboratory, and SMs on the Shear Strength of Rock Joints and Shear Testing Including Stiffness Controlled Tests and Possible Determination of Normal and Shear Stiffness”

Co-ordinator: Dr. Jose Muralha, Portugal (e-mail: jmuralha@lnec.pt)

Activities: It took some time for the Co-ordinator to find key persons for this WG considering the many aspects of discontinuity shear strength.

Continued on the next page

ISRM Testing Methods Commission: Report for 2009 (cont.)

Submission of the final document to the Commission: Early 2011.

Current members: Prof. Dr. Giovanni Grasselli (Canada), Prof. Yujing Jiang (Japan), and Assoc. Prof. Dr. Manfred Blummel (Austria), Dr. Panayiotis Chrysanthakis (NGI, Norway).

WG for “Upgraded SMs for the Quantitative Description of Discontinuities in Rock Masses”

Co-ordinator: Prof. Dr. John P. Harrison, UK (e-mail: j.harrison@imperial.ac.uk)

Activities: It took some time for the Co-ordinator to find key persons to contribute to this WG including many aspects of discontinuities. The Content of the upgraded SM has been submitted to the Commission.

Submission of the final document to the Commission: Early 2011.

Current members: Dr. Stavros Bandis (Greece), Prof. Dr. Giovanni Grasselli (Canada), Dr. Robert Hack (The Netherlands), Prof. Dr. Steve Hencher (UK), Prof. Dr. Doug Stead (Canada), Dr. Flavio Lanaro (Sweden), Dr. Fulvio Tonon (USA), Prof. Dr. Zhang Liao Yang (USA), Dr. Nuno Grossmann (Portugal).

WG on “ K_{IIC} of Rocks”

Co-ordinator: Prof. Dr. Ove Stephansson, Sweden (e-mail: ove@gfz-potsdam.de)

The WG is in the process of writing up the Suggested Method for Mode II fracture toughness testing of rocks and plans to have a first draft to be distributed for review in 2009.

WG for “Representing ISRM Suggested Methods in Electronic Form (RISMEF)”

Co-ordinator: Prof. Dr. Zuyu Chen, China (e-mail: chenzuyu@iwhr.com)

Activities:

- A small seminar was held at SINOROCK2009 in Hong Kong. This



Task force meeting organised by the RISMEF WG in Wuhan, China on 13 May 2009: From left to right in the front row: Xia-Ting Feng, John P. Harrison, Resat Ulusay, John A. Hudson, Alvaro Gonzales-Garcia

meeting was aimed at promoting further study on the standardisation and digitalisation of rock mechanics test methods.

- Efforts will be made on linking the database of rock mechanics tests to the ISRM website, in order to provide a widely shared network on the basis of XML technology, to store, query and browse the XML documents of test data from the database via the internet.

International Society for Rock Mechanics
ISRM Lecture Tour of China 2009
Organised by Professor Cai Meifeng

THE ISRM “BLUE BOOK” CONTAINING ALL THE ISRM SUGGESTED METHODS

Resat Ulusay
Professor
Hacettepe University, Turkey
President of the ISRM Commission
on Testing Methods

Presentation on the Blue Book during the ISRM China Lecture Tour
This Powerpoint presentation was given at all the venues of the ISRM Lecture Tour, five Universities and the Chinese Academy of Sciences

- For the first stage, the RISMEF WG chose 7 SMs from the Blue Book for conducting the procedures of standardisation and digitalisation. As pilot work, the WG established electronic formats for the SM for Determining Block Punch Strength Index (BPI) and the SM for Triaxial Testing. Based on VBA, a programme language, an electronic format is developed to store the data of both tests in Microsoft Office EXCEL, plus the BPI values of the tested rock samples and triaxial test data. Using VBA technology and the XSL document, the database in EXCEL format is transferred to the XML document format which can be shown via the web.
- The RISMEF WG organized a Task Force Meeting at the Institute of Rock and Soil Mechanics, Chinese Academy of Sciences in Wuhan, China, on 13 May 2009 during the ISRM China Lecture Tour. Resat Ulusay (President of the Commission on Testing Methods), John A. Hudson (ISRM President and Commission member) and Xia-Ting Feng (Member of RISMEF, ISRM Vice President-

at-Large and Commission member), John P. Harrison (Imperial College, UK), Alvaro Gonzales-Garcia (ISRM Vice President for South America) and some of the members of the WG participated in this meeting.

9. The 2009 ISRM Lecture Tour was organised by Prof. Dr. Cai Meifeng, the President of the ISRM Commission on Education, between 9-15 May, 2009. Prof. John A. Hudson, Prof. Dr. John P. Harrison, Dr. Tony Meyers and Prof. Dr. Resat Ulusay gave lectures at a total of five Universities and an Institute in Beijing, Nanjing, Wuhan and Hong Kong. The lectures covered the principles of rock mechanics and the process of rock characterisation and design for rock engineering. During this tour the Blue Book was also introduced to the Chinese rock mechanics community by Resat Ulusay, and the participants were encouraged to assist by joining appropriate WGs established by the Commission, and to develop new SMs and/or to upgrade the current SMs.

10. The brochure prepared to introduce the Blue Book to the geo-engineering community was distributed during the ISRM China Lecture Tour and SINO-ROCK2009. It was also sent to ARMA and it will appear in the May 2009 issue of the Bulletin of the Engineering Geology and the Environment.

11. The Commission's annual meeting was held in Hong Kong on May 18, 2009 before the SINOROCK2009 Symposium.



Testing Methods Commission meeting in May 2009 in Hong Kong
I to r: Xia-Ting Feng, Sergio Fontoura, Francois Malan, Resat Ulusay,
Eda de Quadros, John A Hudson, Claus Erichsen

ISRM Membership: Joining, Benefits and Fees

How to become an ISRM Member

Membership of the Society consists of Individual Members within the approved National Groups, Corresponding Members & Corporate Members:

For Individual Membership apply for membership of the ISRM through your National Group, this being the most recommended type of membership for the development of the Society. However, because some countries do not have a National Group, or due to the preference shown by a candidate for membership directly to the Society through its Secretariat, the category of **Corresponding Members** was created, the amount of the annual membership fee to be paid, depending on the existence of an approved National Group in the respective country, as stated in the Membership Table of Fees.

For Corporate Membership (Companies or Organisations) apply directly to the Secretariat or through your National Groups.

For a national organisation to be recognised as an **ISRM National Group**, it is necessary to formally apply to the President through the Secretary-General for recognition according to the ISRM statutes. This should be an organisation, such as a society or a committee that represents Rock Mechanics in that country, either solely concerned with Rock Mechanics, or as part of a broader field of scientific or engineering interest. Each country shall have no more than one National Group.

Benefits for ISRM Members

The current benefits for ISRM members are:

Individual and Corresponding Members

- 1 copy of the ISRM News Journal
- ISRM Newsletter
- Members' area access in the ISRM website (download of Suggested Methods & Reports, participation in Discussion Forums, etc.)
- Right to participate in the ISRM Commissions and FedIGS Joint Technical Commissions
- Registration at an advantageous rate at the ISRM Congress and International and Regional ISRM Symposia

- Personal subscription to the International Journal of Rock Mechanics and Mining Sciences at a discounted price
- Personal subscription to Rock Mechanics and Rock Engineering at a discounted price.

Corporate Members

- Listed in the ISRM website, with a link to the Company's website
- Listed in the ISRM News Journal
- Access to the ISRM website Members' area
- ISRM Newsletter
- 1 copy of the ISRM News Journal
- 1 registration at an advantageous rate as an ISRM member at the ISRM Congress and International and Regional Symposia.

Annual Fees

1. National Groups

National Groups shall pay to the Society a basic fee, this amount depending on the number of Members, plus a fixed amount for each Individual and Corporate Member, according to the following scale (in Euros, €).

National Group Fee:

- with 10 individual members or less: €33.00;
- with more than 10 and less than 40 individual members: $\text{€}3 \times \text{no. of members} + \text{€}3$;
- with 40+ individual members : €120.00.

Individual Member Fee: €8.00

Corporate Member Fee: €160.00

2. Corresponding Members

Corresponding Members shall pay to the Society an annual fee. In order to encourage membership of individuals through the ISRM National Groups, this annual fee is different for Corresponding Members from countries with or without a National Group:

- Fee for Corresponding Members from countries without a National Group: €20;
- Fee for Corresponding Members from countries with a National Group: €20 in the first year; €40 in the subsequent years.

3. Corporate Members €160.00

Organising ISRM Symposia and ISRM Events

Organisation of ISRM-sponsored meetings

The Society shall sponsor a co-ordinated programme of National, Regional and International Symposia, and Specialised Conferences.

National Groups seeking to host a Regional or International Symposium shall submit a written proposal to the Secretariat, at least one and preferably two to three years before the date of that Symposium. The ISRM International Symposium differs from ISRM Regional Symposia in that it is the selected venue for the annual meetings of the ISRM Council, Board, and Commissions of the Society.

National Groups seeking to host a Specialised Conference sponsored by the ISRM shall submit a written proposal to the Secretariat, if possible one year before the date of that Conference, for approval by the Board. ISRM Specialised Conferences are events that may not have the format of a Symposium, are usually of a smaller nature and are focused on a specialised theme.

ISRM sponsorship shall be determined by such considerations as technical content, timing in relation to other meetings, cost and benefits to delegates and the organiser's experience in running similar meetings.

To apply for a Regional or International Symposium or for a Specialised Conference, fill in the appropriate application form available at: <http://www.isrm.net/gca/index.php?id=195>.

All publicity materials and the proceedings themselves are to make reference to ISRM sponsorship, by use of the name and logo of ISRM.

Organisation of a Congress of the Society

Every four years, the Society holds a Congress on themes of general interest to the majority of the membership. The responsibility for organising a Congress shall belong to the National Group of the country in which the Congress is to be held.

In accordance with the ISRM By-law No. 4 *Organisation of a Congress of the Society*, National Groups wishing to host a Congress of the Society shall submit a written proposal at the annual meeting of the Council six years before the Congress. Contact the ISRM Secretariat for further details: secretariat.isrm@lnec.pt

ISRM Coming Events (as at publication date)

31 May - 22 June 2010, Puerto de la Cruz, Tenerife, Spain – 3rd International Workshop on Rock Mechanics and Geo-Engineering in Volcanic Environments: an ISRM-Sponsored Specialised Conference

13-14 June 2010, Switzerland – 2nd ISRM Annual Field Trip, see page 98

15-18 June 2010, Lausanne, Switzerland – EUROCK2010, the 2010 ISRM-sponsored Regional Symposium, see page 99.

25-27 August 2010, Beijing, China – 5th International Symposium on In-situ Rock Stress: an ISRM-sponsored Specialised Conference

23-27 October 2010, New Delhi, India – 6th Asian Rock Mechanics Symposium, Advances in Rock Engineering: the 2010 ISRM-sponsored International Symposium, see back page of this Issue

16-21 October 2011, Beijing, China – ISRM 12th International Congress on Rock Mechanics: the 2011 ISRM International Congress



The ISRM booth, SINOROCK Symposium, May 2009
l to r: Resat Ulusay, John A Hudson, Sofia Meess, Hadi Ghazvinian, Luis Lamas

John A. Hudson, UK (john.a.hudson@gmail.com)

Rock Engineering in China

It was noted earlier that, as a result of the voting at the ISRM Council Meeting in May, 2009, Prof. Xia-Ting Feng of the Institute of Rock and Soil Mechanics, Chinese Academy of Sciences, was elected as the next President of the ISRM for the period 2011-2015. His term of office begins immediately after the ISRM 2011 Congress in Beijing. His picture and CV are included on page 28 of this Issue.

The election of Xia-Ting Feng is not only fitting because he is ideally suited to the post but because of the country that he represents – with its enormous amount of rock mechanics and rock engineering which is currently underway. In view of this, I asked Prof. Qian Qihu, President of the Chinese Society for Rock Mechanics and Engineering (CSRME), if he would write a paper on rock engineering in China. He kindly agreed and the paper is presented in abridged form on pages 61-71 following. The full 37 page paper can be obtained through a request to the CSRME HQ at csrmre@163.com.

Some of the statistics in Prof. Qian's paper are truly astonishing: "21 cascade hydropower stations have been planned on the main stream of the Yalong River, among which 10 stations will have a capacity of more than 1000 MW"; "a highway network characterised as '7918' will be constructed by 2020, i.e., 7 rays, 9 longitudinal lines and 18 transverse lines with a total length of about 85,000 km"; "the total length of roads in China will reach 2.3 million km by 2010, and 3 million km by 2020"; "the Qinghai-Tibet Railway is the highest and longest railway constructed in plateau permafrost in the world and the total length from Golmud to Lhasa is 1142 km, among which 960 km of the railway is above elevation 4000 m" – and there are many more such statistics.

Moreover, these statistics are presented within the context of rock mechanics and rock engineering. It is no wonder that some of the most innovative developments, both theoretical and practical, are now emanating from China, as is clear from the information in the paper. Thus, I am extremely grateful for Prof. Qian and his colleagues for compiling such an informative paper.

Rock Dynamics

There are many subjects in rock mechanics that have received a great deal of research attention over the years but, for some reason, rock dynamics is not one of them. This is probably because of the difficulty of conducting experiments in the laboratory and in the field. Also, although we have a good theoretical background based on stress waves in elastic solids, unfortunately the rock mass is not elastic and so the refraction and reflection of stress waves at fracture boundaries and the attenuation have to be taken into account as well. Furthermore, there is a wide spectrum of strain rates when we consider rock dynamics in its wider sense.

For these reasons, the ISRM Rock Dynamics Commission was established under the Presidency of Dr Yingxin Zhou of the Defence Science and Technology Agency in Singapore to provide a forum for the sharing and exchange of knowledge in rock dynamics research, organising meetings and co-ordinating rock dynamic research activities within the ISRM community with a view to producing useful related documents, see page 48 of this Issue.

Together with Prof Jian Zhao, he organised a Rock Dynamics Workshop in June, 2009, at the EPFL in Switzerland. This Workshop, which I attended, was most successful and the six papers on rock dynamics on pages 72-95 of this Issue are abridged versions of some of the papers presented there. These papers represent a spectrum of rock dynamics research from the careful laboratory testing of rock via the split Hopkinson bar with controlled wave shapes, to state-of-the-art numerical modelling, to interpretation of past earthquake effects, to macro explosive *in situ* cavern testing, and interpretation of the dynamics of the 2008 Wenchuan earthquake in China.

These papers illustrate both the complexity and the excitement of rock dynamics work, and I am grateful to the authors for the difficult job that they undertook in reducing their longer contributions to four pages each without losing any crucial content. I am sure that readers will be intrigued by the work reported in these six rock dynamics papers.

Qihu Qian and Zulie Fang, Chinese Society of Rock Mechanics and Engineering, Beijing, China (csrme@163.com)

Advances in rock engineering and technology in China

In recent years, Chinese researchers and engineers in rock mechanics and the rock engineering field have encountered technical difficulties and challenges during construction of national key projects, for instance,

- water conservancy and hydropower projects including the Three Gorges Project, the Gezhouba project, the Xiaolangdi project, the Ertan project, the south-north water diversion project;
- mining engineering projects at Daye, Panzhihua, Jinchuan;
- Chengdu-Kunming, Nanning-Kunming, Beijing-Kowloon and Qinghai-Tibet railway projects;
- Fushun, Datong, Lianghuai and Yanzhou coal mines;
- petroleum engineering projects at Daqing, Shengli and Karamay,
- nuclear power engineering projects at Qinshan, Daya Bay and Ling'ao,
- subway projects in Beijing, Shanghai, Guangzhou, Shenzhen and
- other thousands of small and medium-sized construction projects. Substantial work has been carried out and fruitful results have been achieved.

Some advances in rock engineering and technology in China in recent years will be introduced briefly in the following sections.

Rock engineering in hydro-power projects

The most representative hydropower project is the Three Gorges Project, which has been completed.

Stability and monitoring techniques for ship lock high slopes in the Three Gorges Project

One of the major achievements in the construction of the Three Gorges Project is the stability and monitoring techniques for shiplock high slopes. The permanent shiplock is located in the mountain on the left bank of the dam. It is a double-channel and continuous five-step shiplock by

deep excavation in the mountain. The total length of the shiplock is 6442 m, with the main segment (lock chamber) being 1621 m. The shiplock is in a

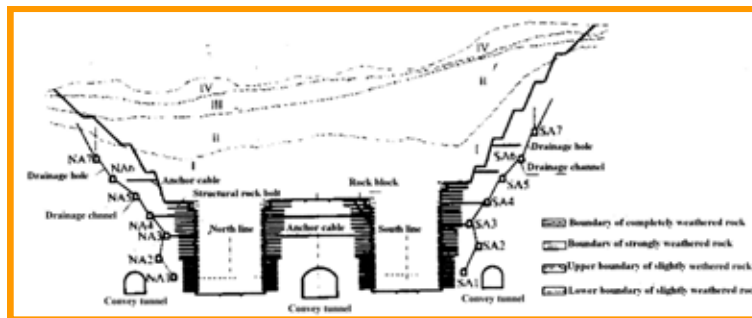


Figure 1 Cross-sectional view of typical anchoring reinforcement of the shiplock high slopes

“W” shape, as shown in Figure 1.

The high rock slope was artificially excavated, with maximum excavated height of 173 m. The maximum slope height was 160 m. The slope with height more than 120 m covered a range of about 460 m in length. The open-cut earth/rock volume was $4196 \times 104 \text{ m}^3$ and $9.8 \times 105 \text{ m}^3$ for tunnel excavation. A 50-60 m division pier was retained between the two channels of the permanent shiplock. The maximum gross head in the shiplock is 113 m, and the largest single-step working head for the reverse tainter valve of the underground filling & emptying system is 45.2 m.

The permanent shiplock is the one with the largest scale, the most steps and the highest total design head in the world. Compared to common high slopes, the high slopes of the permanent shiplock have the following features: the slope is a steep high slope through deep cutting into the mountain, it is of great height, complex form, has extensive coverage, with fully released stresses, and exhibits clear unloading and inhomogeneous characteristics.

In order to ensure normal and smooth operation of the system, the requirements on slope stability and deformation were very stringent. The slope construction was very difficult, with many disturbances and a tight schedule. Besides the high-intensity construction at ground surface, it was even more difficult to construct the narrow, deep and steep vertical side walls of the shiplock. In addition, the side walls were constructed simulta-

neously with underground tunnels and shafts. How to solve the interaction between excavation to minimise the damage to the rock masses and to ensure construction safety were the challenging problems.

The study on the design of the Three Gorges shiplock was started from the end of 1950s. The construction was commenced in 1994, and the shiplock was put into operation in June 2003. It is a collection of comprehensive applications of advanced multi-disciplinary techniques/methods and research achievements. Over the last few decades, hundreds of researchers and technical staff from universities, research institutes, design institutes and construction companies have conducted joint research on engineering geological studies of the high slopes, mechanical properties of the rock masses, underground seepage and drainage measures, optimisation of construction methods and excavation and blasting techniques, anchoring techniques for high slopes, stability analysis of high slopes, etc.

The research provided a large amount of qualitative and quantitative data on the stability of the steep high slopes of the Three Gorges shiplock. A variety of two-dimensional and three-dimensional numerical modelling was performed. The results provided a reliable basis for design, construction and scientific evaluation of slope stability.

The technical achievements for the stability evaluation and monitoring for the high slopes of the Three Gorges shiplock are manifold. The comprehensive anchoring technology is as follows. About 36,000 ordinary steel rockbolts, 100,000 high-strength structural bolts, 229 anchoring cables with 1000 kN prestress and 3975 anchoring cables with 3000 kN prestress were installed and 1054 rock blocks were supported in the high slope of the Three Gorges shiplock. The anchored volume and the quantity of reinforced blocks are the largest in the world.

Due to the huge scale of the slope anchorage for the Three Gorges shiplock, the structural form of anchoring cables and construction technology are related directly to the progress and cost of the project. In order to fully utilise the performance of anchoring cables with different structural forms, different types of cables were employed at different parts of the ship lock, according to the struc-

tural features of the shiplock slopes.

The anchorage cables used in the high slope of the shiplock included: end-anchored cables with 1000 kN or 3000 kN prestress and cross-anchored cables with 3000 kN prestress. Except for 113 cables for monitoring and 121 cables for reinforcement of the concrete structure at the lock head which were unbonded, the rest were fully bonded anchor cables.

For the 1000 kN end-anchored cables, the designed pre-stress was 1000 kN and the over-tension was 1150 kN. 7 steel wire strands with diameter of 15.24 mm and strength of 1860 MPa were used. The designed strength utilisation coefficient was 0.55, and the strength utilisation coefficient for over-tension was 0.63. The boreholes were 30-40 m in length and 115 mm in diameter. The internal anchored section was 5 m in length and in a date-pit shape.

For the 3000 kN end-anchored cables, the boreholes were 30-60 m in length and 165 mm in diameter. The internal anchored section was 8 m in length. The designed pre-stress was 3000 kN and the over-tension was 3450 kN. 19 steel wire strands with diameter of 15.24 mm and strength of 1860 MPa were used. The designed strength utilisation coefficient was 0.606 and 0.697 for over tension. The other parameters were the same as the 1000 kN anchor cables.

The 3000 kN cross-anchored cables were mainly used for the division pier, the systematic reinforcement of the south and north slopes, cross anchor of the south and north slopes and the deep drainage tunnels and cross anchor of the division pier. Anchor piers were constructed at each end of the cables. The cables were prestressed and unbonded. The boreholes for anchor cables were 40-60 m in length and 165 mm in diameter. The other parameters were the same as the 3000 kN end-anchored cables. Specially designed unbonded anchor cables were used for the concrete structure at the lock head to cater for the possible deformation between concrete and rock masses. In view of the alternating load by the gate at the lock head, the outer anchor head was peeled for 8 m and formed a bonded section. By this means, the outer anchor end was double secured by both anchorage devices and the 8 m bonded section.

Stability analysis of ancient landslides in the Three Gorges reservoir area

Some environmental geological hazards were triggered by the construction of the Three Gorges Project. As for the stability prediction of giant ancient landslides in the Three Gorges reservoir area, researchers from the Bureau of General Reconnaissance of Changjiang Water Resources Commission and China University of Mining and Technology (Beijing) have conducted systematic studies on establishment of a database and location of the ancient landslides, identification of giant landslides, sliding modes and space-time prediction of the reactivated landslides, slope stability and coupled stability analysis since 1996.

a) First of all, aiming at the enormous amount of geological data for landslides in the Three Gorges reservoir area, a three-dimensional geological database was established for the landslides by using 3S visualisation information technology. By interpretation of the overall pattern of the landslides, three-dimensional spatial interpretation of the landslides and the slip surfaces, zoning of slope stability by GIS interpretation, and interpretation of structure suitability, a visualized landslide prediction system was set up. The system was successfully applied in the site selection for relocation of Badong County in the reservoir area.

b) According to the field engineering geological investigation on the typical landslides in the reservoir area (for instance, Huangtupo Landslide, Zhaoshuling Landslide, Wushan Landslide, etc.), these landslides, as a whole, can be classified as bedding landslides, inside which ‘mega landslide rock masses’ were developed. By combined

macro-, meso- and micro-methods, detailed comparisons were made between the giant ‘sliding rock masses’ and ‘background rock masses’, and the scope of giant landslides was identified, as shown in Figure 2.

c) The revival mode of the giant landslides was studied on the basis of engineering geological analysis and laboratory geotechnical test results. The spatial prediction method for local landslide revival was explored according to the classification of surface cracks and mechanical analysis. The temporal prediction method for local landslide revival was established according to the landslide revival mechanism and evolution stages.

d) The landslide prediction system was improved after Year 2005. If a slope is taken as a mechanical system, whether a landslide occurs is decided by the balance between ‘the sliding force’ and ‘the anti-sliding force’. The variation in the mechanical system of the slope can be sensitively reflected on the dynamic landslide map by the monitoring and prediction system. Based on the dynamic characteristics, landslide prediction can be implemented. At present, the remote monitoring and prediction system for landslide hazards has been successfully applied at 102 sites in 7 regions in China. Three landslides were accurately forecasted and loss of human lives and property was avoided.

Stability and support technology for high slopes of hydropower projects in deep river valleys

Other than the Three Gorges Project, a number of large and super-large hydropower stations will be

constructed or are under construction. The capacity of the west-east electricity transmission project is over 150,000 MW. For example, on the main stream of the Jinsha River, a tributary of the Yangtze River, 20 cascade hydropower stations

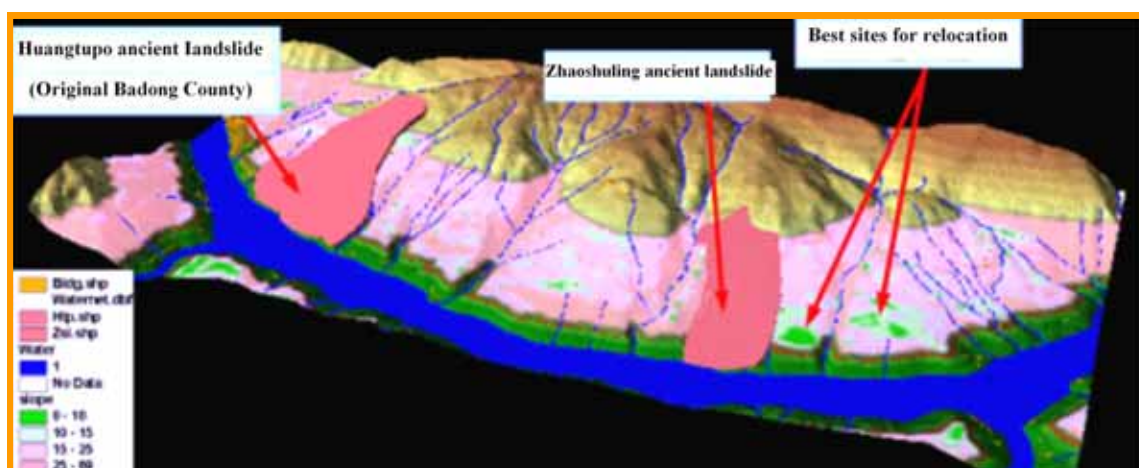


Figure 2. Scope of giant ancient landslides

have been planned, among which 17 hydropower stations have a capacity of over 1,000 MW. The capacity of Xiluodu, Baihetan, Wudongde and Xiangjiaba hydropower stations is more than 5,000 MW. 21 cascade hydropower stations have been planned on the main stream of the Yalong River, among which 10 stations have a capacity of more than 1000 MW. The total installed capacity for the Jinping Hydropower Station Stage 1 and Stage 2 is 8,400 MW. 22 cascade hydropower stations have been planned on the main stream of the Dadu River, among which 7 stations have a capacity of more than 1,000 MW. The capacity of the Pubugou Hydropower Station is 3,600 MW.

In addition, the Xiaowan and Nuozhadu Hydropower Stations on the Lancang River, Goupitan Hydropower Station on the Wu River, Longtan Hydropower Station on the Hongshui River, and Laxiwa Hydropower Station on the upper reaches of the Yellow River are planned or under construction.

Most of the power stations are located in the transition zone of the Qinghai-Tibet Plateau to the Sichuan Basin. Tectonic movement led to the rapid uplift of the Qinghai-Tibet Plateau. A series of major rivers and deep river valleys with elevation differences of 2000-3000 m formed, as well as the well-known major fault zones and seismic zones in west China. Therefore, the geological conditions are complicated. During the development of water resources, high slope problems are frequently encountered in such complex large-scale engineering projects. This type of high slope has the following prominent features:

- the natural slope is very steep. The slope angle is generally more than 45° , with most above 70° - 90° . The valley depth is usually more than 1,000 m;
- the height for the cut slope is large, usually more than 300 m, with the maximum more than 600 m; and
- the geological conditions of the slope are complicated, featured by faults, high geostresses, intensive unloading and large unloading depth. Jinping Hydropower Station Stage I is a typical example.

Jinping Hydropower Station Stage I is located on the river between Pusiluogou and Shoupagou, which flows in a $N25^\circ E$ direction. The water level

is 1635 m during the dry season and the water surface width is 80-100 m.

The project area is typically a deep V-shaped valley, with relative height difference of 1500-1,700 m. The left bank is a counter slope. Below elevation 1,820-1,900 m is marble with slope angles of 55° - 70° . Above is sand-slate with slope angles of 40° - 50° . The local topographic feature is characterised by alternative ridges and gullies. The left bank is a dipping marble slope. The topography is featured by alternative steep and gentle terraces. The slope angles for the steep sections are 70° - 90° , and about 40° for the gentle sections.

Toppling deformation is prevalent in the sand-slate above 1,900 m elevation on the left bank. The horizontal deformation reaches 50 m in the ridges and about 30 m in the gullies. A wide range of toppling deformation in the deep strata may be related to the closed reverse syncline and relatively soft sand-slate. It becomes one of the controlling factors in slope stability on the left bank.

Chengdu Hydroelectric Investigation & Design Institute, together with a number of research institutes and universities in China, conducted in-depth and detailed studies of the dam site. The engineering geological conditions and main engineering geological and rock mechanics problems at the site have been identified. Stability analysis and calculations have been carried out by different means and for a number of modules and operating regimes, which provided the basis for design. In combination with the topographic and geological conditions at the site, the principle of 'strong reinforcement for steep slope' and 'dynamic design and information-based construction' was adopted. The main measures included drainage of surface and ground water, anchor cables and shear retaining structures. Together with slope surface protection, grouting reinforcement and other comprehensive treatment methods, the reinforcement measures were proven effective, as indicated by the monitoring data.

Slope monitoring and back-analysis

According to the different geological conditions and failure modes for different sections of the slope on the left bank, pertinent monitoring



Figure 3. Overview of the slope on the left bank under construction

schemes were designed. The deformation monitoring system consists of a monitoring and control network, monitoring of deformation in the surface rock and monitoring of deformation in the deep rock. The cracks deep in the abutment slope were extremely harmful to the slope stability and the stability of the slope under rupture deformation was crucial to the project safety; hence, this section was the focus for monitoring. The rock deformation and the stress state were monitored. Meanwhile, groundwater and seepage, vibration during blasting and rock relaxation were monitored.

Through continuous monitoring of the entire process and using statistics, compilation, analysis and back-analysis of the original monitoring data on deformation, seepage, strain and stress, the working condition and safety of the slope can be accessed during the construction period, the water storage period and the operation period. Abnormal phenomena for parameters and factors possibly endangering the structures can be captured in time, followed by evaluation of slope stability and safety. Treatment measures and suggestions on decision-making can be proposed accordingly, so as to ensure the slope safety. Figure 3 shows an overview of the slope on the left bank under construction.

Support of the underground cavern complex

For the construction of large or medium-scale hydro-power projects, the underground cavern complex is one of the key structures. Generally, unstable geological conditions are encountered unavoidably, for instance, thick weak layers and argillaceous interbeds exist in the surrounding rock (it is even more unfavourable if they are at the elevation where anchored cranes are installed); faults and broken zones intersect the axis of the

underground caverns at a small angle or result in large movable blocks together with other structural planes; the surrounding rock consists of alternative hard and soft layers, or soft rock layers are overlain by hard rock layers. Through comprehensive analysis and verification, proper support measures can be proposed in response to the encountered geological conditions.

Good results were achieved in the Shuibuya Hydropower Station project on the Qingjiang River, Hubei Province. The Shuibuya Hydrojunction is located in the middle reaches of the Qingjiang River in Badong County, Hubei Province, China. The normal reservoir level is 400 m and the total reservoir capacity is 4.58 billion m³. The reservoir for Shuibuya Hydrojunction is the first reservoir for the cascade development of the Qingjiang River. The overburden depth for the underground cavern complex is 400-450 m. The elevation of the roof of the powerhouse is 230.47 m and 162.80 m for the tailrace tunnel floor. The powerhouse dimensions are 23.00m×150.00m×67.67m (width×length×height). The width of the crane beam is 23 m at the top and 21.5 m at the bottom. The azimuth axis of the powerhouse is at 296°. The stratum attitude is 245°∠8°~15°. The angle between the axis of the power house and the stratigraphic strike is 39°.

The cavern complex passes through alternative hard and soft rock layers. A large number of inter-layer shear zones exist at the interface of the soft

and hard rock layers. The shear zones are characterised by strength softening and low shear strength. Shear slip or extrusion by creep deformation is likely to occur due to unloading during excavation, which is extremely harmful to excavation of the cavern complex and stability of the surrounding rock. In view of the above-mentioned geological conditions, in combination with the layout optimisation for the underground cavern complex, the researchers from Changjiang River Scientific Research Institute proposed a systematic and comprehensive reinforcement scheme for the surrounding rock of the cavern complex. As proper reinforcement measures were taken, the construction of the cavern complex of Shuibuya Hydropower Station was a success. Figure 4 shows the reinforcement layout at a typical cross-section of a cavern.

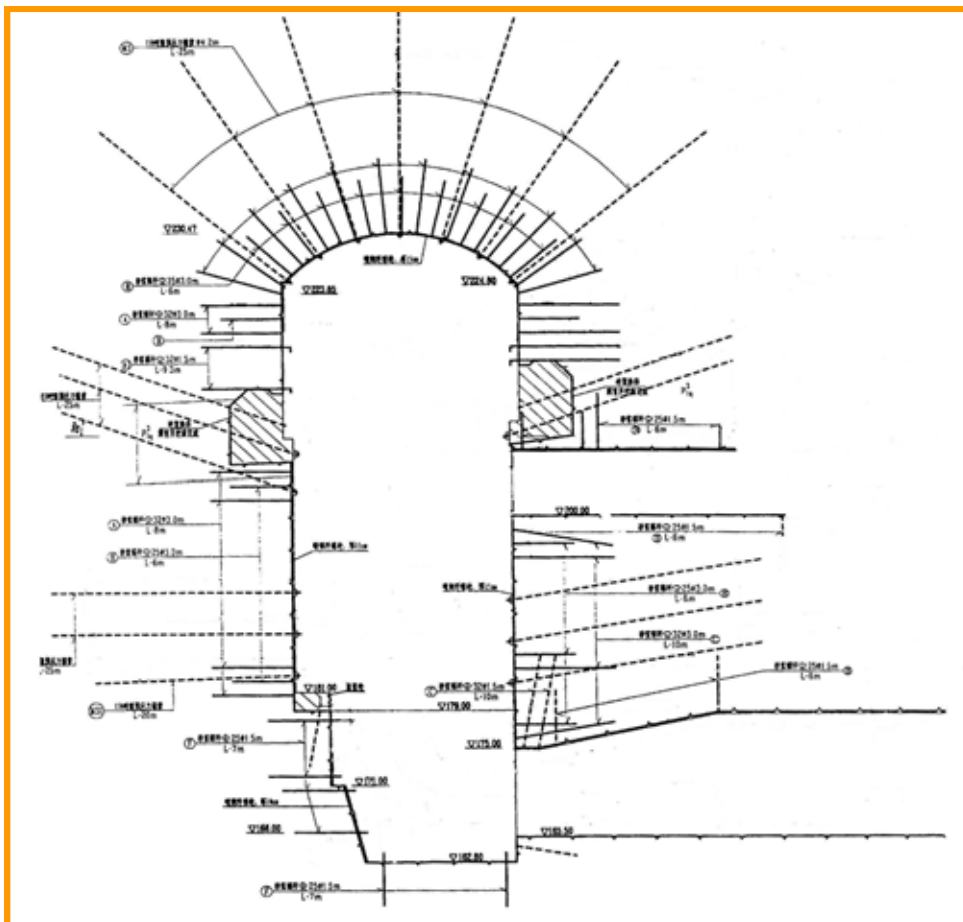


Figure 4. Reinforcement layout at a typical cross-section of a cavern

Rock engineering in highway and railway projects

According to the plan, a highway network characterised as “7918” will be constructed by 2020, i.e., 7 rays, 9 longitudinal lines and 18 transverse lines with a total length of about 85,000 km. Among them, the total length of the 7 rays from Beijing to capital cities of other provinces is 18,000 km. The highway network will connect all the 319 cities with a population of more than 200,000 inhabitants. In addition to highways, roads of different grades are under construction. The total length of roads in China will reach 2.3 million km by 2010, and 3 million km by 2020.

By the end of the year 2007, the railway traffic extent in China was 78,000 km, ranked no. 1 in Asia. According to the plan, the railway traffic length will reach 100,000 km before 2020. 4 longitudinal and 4 transversal railways have been completed. Moreover, many projects are under construction or to be constructed. Among them, the Beijing-Shanghai high-speed railway under construction has attracted worldwide attention. The total investment is 22.09 billion RMB yuan. It has been the railway project with the highest lump-sum investment.

Study on permafrost engineering for the Qinghai-Tibet Railway

The most prominent achievement in railway construction in recent years is the completion of the Qinghai-Tibet Railway. The Qinghai-Tibet Railway is the highest and longest railway constructed in plateau permafrost in the world. The total distance from Golmud to Lhasa is 1142 km, among which 960 km of the railway is above elevation 4000 m and about 550 km of the railway passes through the permafrost zone. Sporadic permafrost, seasonal frozen soil, wetlands and wetland slopes are widely distributed. Construction of the Qinghai-Tibet Railway in the

permafrost area is the most difficult technical challenge.

The China Railway First Survey and Design Institute conducted studies on the impacts of climate change. National technical standards for site investigation, design and construction of railways in plateau permafrost were developed. The design ideas of induced cooling, foundation cooling and protection of frozen soil and key parameters were identified. Air-cooling rubble embankment, subgrade with thermosyphons and bridges across special harmful frozen sections were adopted innovatively. A complete set of construction techniques for subgrade in permafrost was successfully developed, for instance, tunnel lining against frost-heave.

Road and railway tunnels

Great achievements have been made in tunnel construction techniques in road and railway projects in recent years. 12,000 tunnels of different types have been put into use in road and railway industries, extending over 7000 km. Among them, more than 7,000 tunnels are railway tunnels with a total length of over 4000 km; over 4,000 tunnels are road tunnels with a total length of more than 2000 km. Tunnels under river beds are mainly in the Shanghai region. 8 tunnels crossing the Huangpu River have been constructed, and another 5 tunnels are being constructed or to be constructed. Other tunnels under construction include the tunnel crossing the Yellow River and Yangtze River for the South-North Water Diversion Project and tunnels in cities. The submarine tunnels under construction are the Xiamen-Xiang'an tunnel, the Jiaozhou Bay estuary tunnel, the Guangzhou Biological Island-University City tunnel and the Shiziyang railway tunnel. Tunnels to be constructed include the Qiongzhou Strait tunnel, the Bohai Bay (Dalian-Penglai) tunnel, the Hangzhou Bay (Shanghai-Ningbo) tunnel and Dalian Bay tunnel.

Construction techniques adopted for the Fenghuoshan Tunnel in permafrost

The landmark achievement in tunnel construction techniques is the Fenghuoshan Tunnel in permafrost for the Qinghai-Tibet Railway. It is the highest tunnel (track surface elevation at 4905 m) in

the world and a key project for construction of the Qinghai-Tibet Railway. The tunnel is 1338 m in length and passes through the permafrost zone. The tunnel entrance and shallow tunnel section are located within permafrost with high ice content. The ice content was more than 50%. Fissured ice is prevalent for the main tunnel section. No similar tunnel construction experience can be learnt from and the construction was extremely difficult. In the Fenghuoshan region, hypoxia is severe and the ecology is fragile, which presented particular challenges to construction.

Construction of the Erlangshan tunnel and Zhegushan tunnel of the Sichuan-Tibet highway

Similar achievements have been made in the construction of the Erlangshan Tunnel and Zhegushan Tunnel of the Sichuan-Tibet Highway. Research staff from the Southwest Jiaotong University and other Institutes conducted studies on three types of key technical problems: namely, complex topographical and geological conditions, harsh climatic conditions and special operational conditions for large high-altitude highway tunnels. A number of comprehensive technical achievements have been made after years of study.

A seismic deformation method was proposed, based on the rock-structure system and beam-spring interaction. Together with dynamic analysis and shake table model test results, different shock absorption measures were adopted according to the cross-sectional characteristics of highway tunnels. These measures included addition of shock absorption layers, use of polymer or steel fibre reinforced concrete lining, etc. for highway tunnels located in an intensive seismic zone.

The seismic deformation method was verified. The relation between the parameters of steel fibre reinforced concrete structure and the initial stress softening factor and cracking resistance of the structure was identified. The seismic effect was illustrated in term of the damping ratio of the shock absorption layer and the lining and stiffness ratio of the shock absorption layer and the lining. Shock absorption measures were proposed for highway tunnels in intensive seismic zones.

The study shows that the smaller the stiffness ratio of the shock absorption layer and the lining, the larger the seismic effect. The mass ratio of the shock absorption layer and the lining is affected by the stiffness ratio. When the stiffness ratio is less than 1, the smaller the mass ratio, the greater the seismic effect. This is because, when the inertia of the surrounding rock is relatively small, the internal force is controlled by the stiffness of the surrounding rock. The stress softening factor is influenced by the direction coefficient, slenderness ratio, mass content, grip force of the steel fibres and the lining thickness. With the increase of the direction coefficient, slenderness ratio, mass content, grip force of steel fibres, the initial stress softening factor increases. With the increase of the lining thickness and tensile strength, the initial stress softening factor decreases.

The design of the tunnel cross section was optimised from the point of view of the seismic effect. The shock absorption measure at shallow tunnel sections was proposed, i.e., a shock absorption layer between the tunnel lining and the soil stratum. The original lining-rock system was converted to a lining-shock absorption layer system and hence the seismic intensity and manner acting on the structure can be reduced or changed.

A technical system for the design of long highway tunnels in seasonal frost-heave and freeze-

thaw areas was established. Anti-freeze has been one of the key topics in studies on permafrost at home and abroad. The study on rock tunnels in seasonal frost-heave and freeze-thaw areas was a blank. Field testing, laboratory tests and numerical modelling were employed to investigate the freeze-thaw, frost heave and heat transfer characteristics of the surrounding rock in the seasonal frost heave and freeze-thaw areas, on the basis of comprehensive analysis of the present development trend of anti-freeze techniques for tunnels and aiming at the most promising anti-freeze measure by heat insulation.

The theoretical model for heat exchange between air and the surrounding rock at the entrance and exit of extra long highway tunnels and different tunnel sections, the influence of frost heave of the surrounding rock on the tunnel, the variation model of the temperature in the tunnel, reasonable thickness and length of the tunnel prone to freeze hazards, optimised anti-freezing structures for tunnels were proposed.

By application of rock 'epigenetic reformation theory', unloading-deformation fracture mechanics and soft rock mechanics, and the high stress field, the corresponding geomechanical model was established for the first time in the world. The mechanism of rockburst and large deformation in this type of tunnel was proposed, based on the

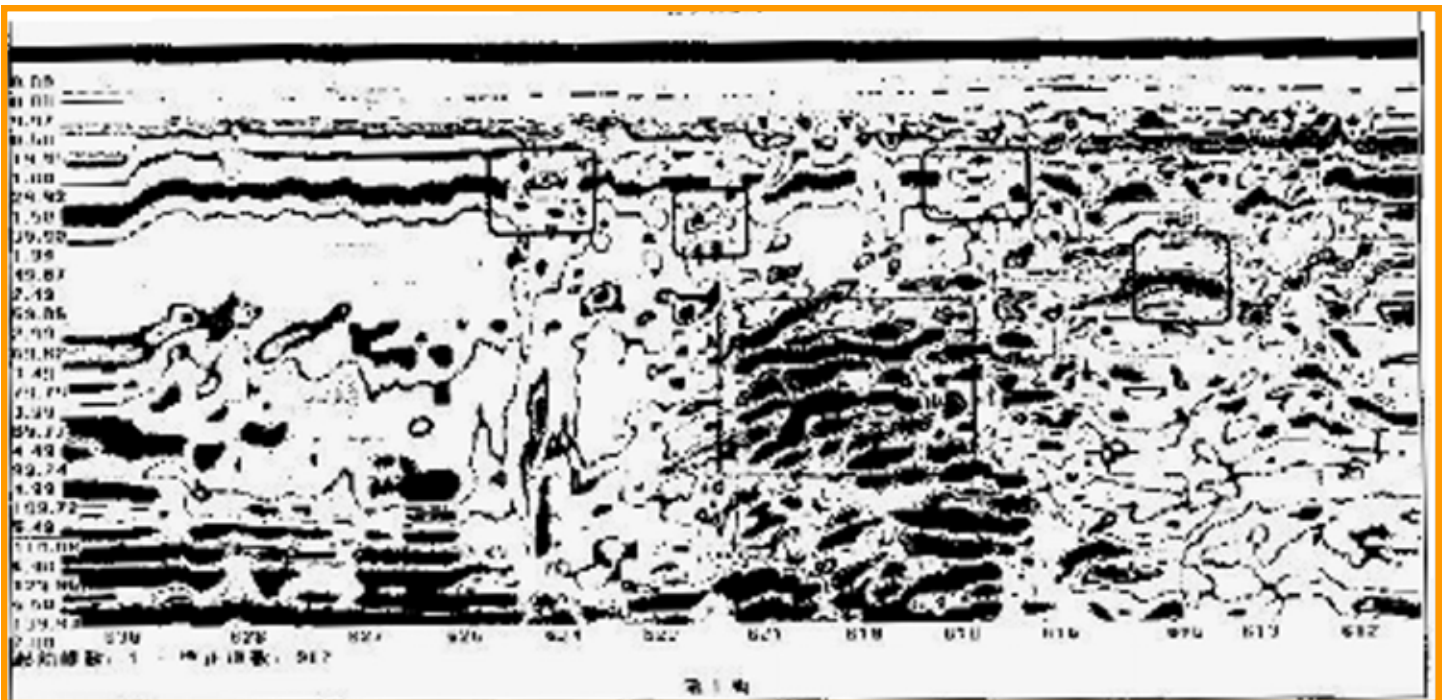


Figure 5. Interpretation of radar results

structural features and construction methods of highway tunnels. The quantitative criterion for classification of rockbursts and large deformations was identified. An integrated technical system for prediction and treatment of rockbursts and large deformation hazards and stability analysis and evaluation for the surrounding rock was established.

Support Techniques for Large Squeezing Deformations in the Wuqiaoling tunnel

The Wuqiaoling Tunnel of the Lanzhou-Xinjiang Railway is currently the longest railway tunnel (with a total length of 20.05 km) in China. The overburden depth is 500-1,100 m for sections under the mountain ridges. The tunnel passes through 'squeezing zones' formed by a number of large regional faults. The large squeezing deformation was significant under the high geo-stresses in the soft rocks. Deformation control was very difficult and presented an unprecedented challenge for design and construction of the tunnel.

Comprehensive study on forecasting adverse geological conditions

For tunnel construction, significant progress has been made on prediction of adverse geological conditions over the last few years. For instance, research staff from Shandong University made a comprehensive study on forecasting for more than 20 karst tunnels of the Shanghai-Chengdu-Xichang Highway, with prediction accuracy of 70%. The main technical advances include:

- a qualitative assessment method for hazard risk of karst tunnels was established;
- the multiple solutions of geophysical investigation of the complexity of geological conditions were studied; and
- a transient electromagnetic device for water inrush and post-processing software for geological radar were developed.

Some results using geological radar are shown in Figure 5 to the left. The radar reflection was of relatively large amplitude and low frequency.

The principle and techniques for comprehensive geological forecasting were thus proposed. The research results were successfully applied in the geological forecast practices for more than 20

karst tunnels, which provided guidance for tunnel construction, helped to avoid water and mud inrush and ensured construction safety.

Mining engineering

China has abundant coal resources, which are currently dominant in the energy structure. Coal output has reached 2.716 billion tons by the year 2008. The corresponding length of annual mine roadway excavation is more than 12,000 km. The mining capacity for black and non-ferrous metals in China is huge. By the year 2008, iron ore production had reached 840 million tonnes and the total output for 10 kinds of non-ferrous metals has been 25,202,800 tonnes. The corresponding annual roadway excavation volume for black and non-ferrous metal mining is enormous.

Innovative techniques for roadway support in mines

For construction of large-scale roadways for underground mining, roadway support is directly related to mining safety, output and efficiency. Aiming at the roadway features in China, research staff from the China Coal Research Institute and other Institutes developed a complete set of innovative techniques for roadway support, integrating theory, methodology, materials, equipment, technology, instruments and technical specifications. Roadway support techniques with independent intellectual property rights in the Chinese context were developed. The techniques can solve complex and difficult roadway support problems, speed up construction of high-yield high-efficiency mines, substantially increase coal output and efficiency and significantly improve safety in roadways.

The main research topics included: support theory of rockbolts for mine roadways, dynamic information design method and software for rockbolt support, rockbolts made of high-strength resin and material for anchor cables, roofbolter and rapid construction techniques, mine pressure monitoring instruments and techniques, combinational reinforcement by rockbolts and grouting and top coal caving, deep mining and other roadway support techniques under complex and difficult conditions. Through continuous scientific and

technological research on roadway support techniques, the main innovative achievements have been as follows.

- The expansion-stability theory for rock bolts was proposed. Systematic rockbolts of high strength and high stiffness should be installed.
- A dynamic information design method for rock bolt support was proposed. Software for rockbolt design was developed, integrating the geomechanical database, initial design, processing of monitoring data, information feedback and design modification.
- Combinational reinforcement techniques were developed with grouted rock bolts, grouted anchor cables and integrated drilling-bolting-grouting method.
- A set of equipment for monitoring mine pressure and safety of roadways was developed. The instruments have been widely applied in the mines and play an important role in optimised design of roadway support, assessment of roadway support and ensuring roadway safety.
- A series of roofbolters was developed. The roofbolters have been continuously improved according to the mine roadway conditions in China.

Meanwhile, based on the available mining equipment in China, by optimising the construction process and a reasonable arrangement of labour, an express construction technology for mine roadways was established with fully mechanised excavation machines and single roofbolter.

The results have been applied to 58 large or medium-scale mines in 20 provinces in China. The technical level for roadway support in China has been improved by leaps and bounds. It has profoundly changed mine exploitation plans and roadway layout styles and played an irreplaceable and important role in the construction of high-production mines, substantial increase of coal output and efficiency and improvement of mine safety in China.

Safe and efficient deep open-pit mining technology

More than 80% of iron ore is produced by open-pit mining. At present, many large or medium-sized open-pit mines have been transformed from

open slope mining to deep pit mining. With the increase of mining depth, the slope becomes higher and steeper. For instance, the vertical height of the slope for Shougang Shuichang Iron Mine reached 670 m and the depth for pit mining was 430 m.

With the increase of slope height and gradient, slope stability and mining safety has deteriorated. However, on the other hand, the increase of slope angle can reduce the volume of excavated rock and lower the production cost. For example, for an open-pit mine with an annual capacity of 10 million tons, if the slope angle increases by 1° , the volume of excavated rock is reduced by 10 million tons. The economic benefit can reach a hundred million RMB. Therefore, it is a double-edged sword. We have to optimise slope design and comprehensively monitor and control slope stability, so as to maximise the slope angle, reduce the excavated rock volume, lower the cost and increase efficiency, under the premise of safe mining.

The overall slope angle for large open-pit mines in China is generally gentle, compared to similar mines abroad. This is mainly determined by the traditional slope design method with engineering analogy and two-dimensional limit equilibrium analysis. Research staff from Beijing University of Science and Technology and Shougang Mining Company, for the first time, adopted a large-scale three-dimensional non-linear finite difference method, discrete element method and three-dimensional limit equilibrium analysis based on GIS for slope stability analysis and design optimisation, on the basis of a large amount of engineering geological and hydrogeological investigations and experiments, stress measurements at the mine and tests on physical and mechanical properties of ore. Among them, the three-dimensional limit equilibrium analysis method based on GIS was used for the first time in the world.

The overall slope angles of Shougang Shuichang Iron Mine were increased by 1° - 6° , with an average increment of 3° - 4° . The slope design and mining optimisation for Shougang Shuichang Iron Mine has reached and surpassed the international advanced level. At the same time, GPS, the Total Station and other devices were used.

Together with network theory, a displacement

monitoring network was established for the Shuichang Iron Mine, which can make dynamic analyses and prediction of slope stability. It provided the basis for taking necessary measures in time and ensuring slope stability. At the same time, a series of technical measures were formulated to ensure slope stability at great depth and strengthen mining safety. The measures included the following:

- according to investigation and prediction of the potential slope failure mode, the corresponding control measures for slope stability were identified;
- as the Shuichang Iron Mine is located in a seismic risk zone, earthquake disaster mitigation techniques for steep high slopes were developed, on the basis of dynamic failure mechanism of slopes; and
- as the Shuichang Iron Mine is adjacent to the Luan River, monitoring and treatment measures for steep high slope failure induced by seepage were identified.

In order to reduce the transportation cost and increase the production efficiency, a semi-continuous transportation system with a new type of high-performance car and belt and automatic real-time dispatching system based on GPS was established.

Through four years of research, the production cost for the Shuichang Iron Mine has dropped significantly and the production efficiency has been improved substantially. From year 2001 to 2004, with the gradual increase of mining depth and haulage height, the ore cost did not increase; instead, it decreased by 32%. Over the four years, the labour productivity had increased by 2.3 times. The labour productivity of the Shuichang Iron Mine was more than 6 times the average level of key mines in the same industry and is ranked No. 1 in China. The mine generates economic benefits of 139 million RMB every year.

Scientific studies of the Shuichang Iron Mine not only improved production and management to the international advanced level, but also solved the common key technical problems for large open pit mines in China and gave a strong impetus to scientific and technological progress and production development for Chinese open mines.

Concluding remarks

From the above Sections, it can be seen that China is No. 1 in the world in term of the quantity of rock engineering, with a large amount of projects, complex geological conditions and unprecedented technical difficulties. In recent years, a series of innovative achievements has been made in rock engineering and technology. Rich experiences have been accumulated in investigation, design, construction and monitoring. Of course, lessons were also learned. They are precious treasures in our rock engineering field. We are willing to share our experiences with researchers and engineers in rock mechanics and rock engineering over the world. Let us work together towards the further development of rock mechanics and engineering and a new era in rock engineering.

Acknowledgements

The authors would like to thank Professors Cai Meifeng, He Manchao, Yuan Liang, Dai Huichao, Li Shucui, Wu Aiqing, Tan Zhongsheng, Kang Hongpu, He Chuan and Song Shengwu for providing relevant data for this article.

Split Hopkinson Pressure Bar (SHPB) Tests on Rocks

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1. Introduction

Understanding the dynamic material responses of rocks is critical in a variety of rock engineering and geophysical applications (quarrying, drilling, rockbursts, rock blasts, rock crushing, earthquakes, projectile penetrations, etc.). However, as yet no recommended methods have been suggested by the International Society of Rock Mechanics (ISRM) to provide guidance for dynamic tests. The dynamic testing results obtained with different methods and instrumentation are so scattered that cross-referencing of others' results is almost impossible. It is thus necessary for the rock mechanics community to develop reliable dynamic testing methods.

To test the dynamic mechanical properties of rocks, one needs a reliable testing device. For testing rocks under high strain rates from 10^2 to 10^3 s^{-1} , the Split Hopkinson Pressure Bar (SHPB) is an ideal choice. The SHPB was invented in 1949 by Kolsky for testing metallic materials (Kolsky, 1949). Shortly after that, the SHPB was used by researchers to test brittle materials, such as concretes, ceramics and rocks. However, some major limitations in using the SHPB for brittle materials were not fully explored until two decades ago. Unlike ductile metals, brittle materials have small failure strains ($< 0.2\%$) and hence, if the loading is too fast, as in a conventional SHPB test, the specimen may fail in a non-uniform manner. To achieve accurate measurements in SHPB tests, one has to make sure that the specimen is experiencing an approximately equilibrium stress state (dynamic stress equilibrium or dynamic force balance). Because it takes 3-4 rounds for the stress wave travelling in the specimen to achieve such an equilibrium state, the dynamic loading should be slow and of appropriately long duration.

The pulse shaping technique was proposed to slow down the loading rate and thus to minimise the so-called inertial effect associated with the stress wave loading (Frew *et al.*, 2002; Xia *et al.*, 2008).

Another problem related to the conventional SHPB tests is that the specimen is subjected to multiple loadings due to the reflection of the wave at the impact end of the incident bar. A momentum-trap technique was proposed to ensure single pulse loading and thus enable valid post-mortem analysis of the recovered specimen (Song and Chen 2004). Using these new techniques with the SHPB, we systematically measured rock dynamic compressive strength and response, dynamic tensile strength, and dynamic fracture toughness. For all these tests, we used core-based specimens to facilitate sample preparation; the rock tested was Laurentian granite.

2. Experimental setup and techniques

A 25 mm diameter SHPB system made of maraging steel was built in the Impact and Fracture Laboratory at the University of Toronto in 2007. The length of the striker bar is 200 mm. The incident bar is 1500 mm long and the transmission bar is 1200 mm long. An eight-channel Sigma digital oscilloscope by Nicolet is used to record and store the strain signals collected from the Wheatstone bridge circuits after amplification. The impact of a striker bar on the free end of the incident bar induces a longitudinal compressive wave propagating in both directions. The left-propagating wave is fully released at the free end of the striker bar and forms the trailing end of the incident compressive pulse (Fig. 1). Upon reaching the bar-specimen interface, part of the incident wave is reflected (reflected wave) and the

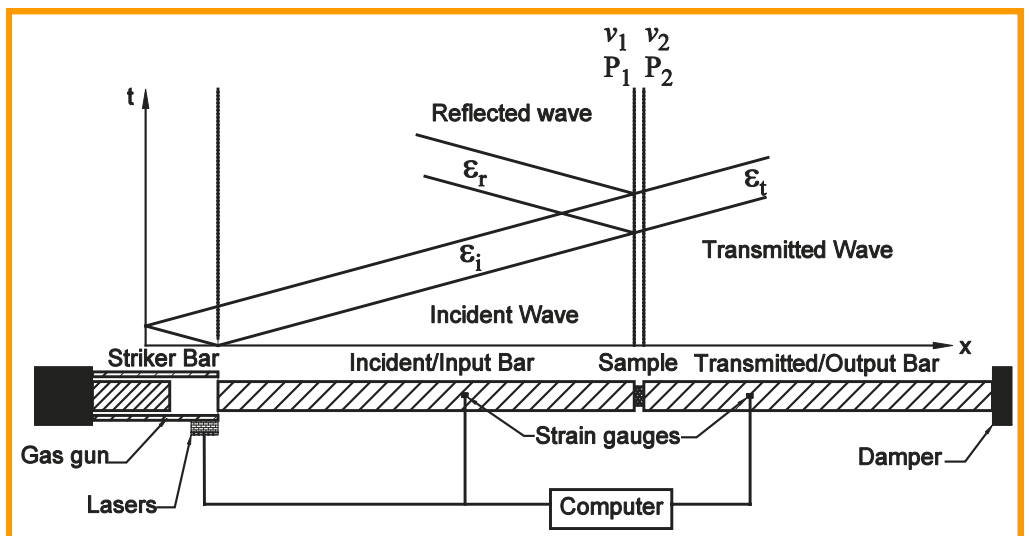


Figure 1. The Split Hopkinson Pressure Bar (SHPB) system.

remainder passes through the specimen to the transmitted bar (transmitted wave).

We denote the input strain pulse, reflected strain pulse and transmitted strain pulse as $\varepsilon_i(t)$, $\varepsilon_r(t)$ and $\varepsilon_t(t)$, respectively. Based on one dimensional stress theory, we can determine the histories of velocity $v(t)$ and force $P(t)$ on the front sample surface denoted by 1 and the back sample surface denoted as 2:

$$v_1 = C(\varepsilon_i - \varepsilon_r); \quad v_2 = C\varepsilon_t$$

$$P_1 = EA(\varepsilon_i + \varepsilon_r); \quad P_2 = EA\varepsilon_t$$

where C is the one dimensional longitudinal stress wave velocity of the bar, E is the Young's modulus of the bar, and A is the area of the bar. These are the key equations in applying the SHPB to dynamic material testing.

To slow down the rising speed of the dynamic load, a thin disc of copper is placed on the impact surface of the incident bar. The striker impacts the pulse shapers before the incident bar, thus generating a non-dispersive ramp pulse propagating into the incident bar and thus facilitating the dynamic force balance (Frew *et al.*, 2002; Xia *et al.*, 2008). The function of the pulse shaper is to: 1) guarantee constant strain rate during the loading; and 2) maintain force equilibrium across the sample. A wide variety of incident pulses can be produced by varying the geometry of the copper disks, Fig. 2. Depending on the materials of testing, a different loading pulse is needed and can be achieved with proper shaper design.

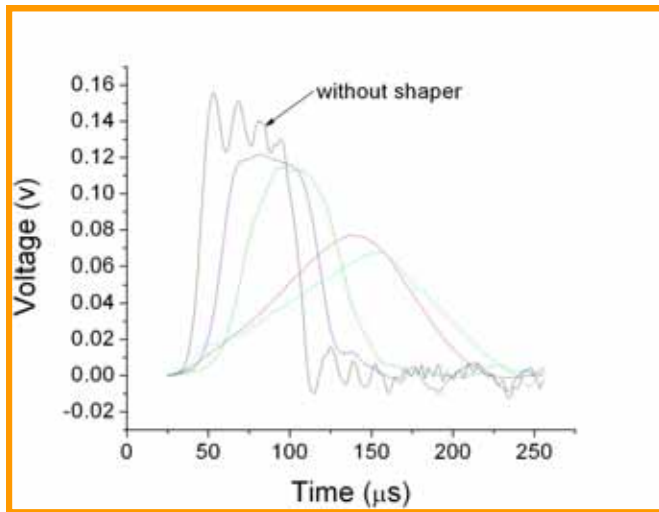


Figure 2. Different loading pulses produced by pulse shaping

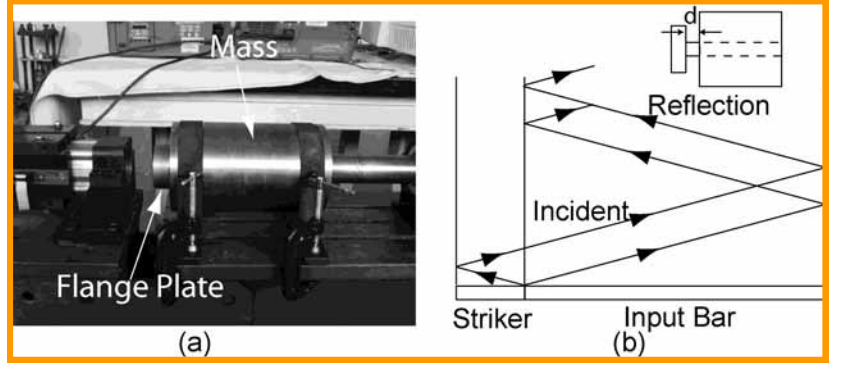


Figure 3. The momentum-trap system: (a) photograph of the system and (b) the x-t diagram

To ensure single pulse loading, the momentum-trap technique is adopted in our Hopkinson bar set up, as shown in Fig. 3. Figure 3a is a photograph of the momentum-trap system, which is composed of a momentum transfer flange that is attached to the impact end of the input bar and a rigid reaction mass that is attached to the bar supporting system. This design was first used by Song and Chen (2004).

As shown in Fig. 3b, there is a gap between the flange and the rigid mass. The distance of the gap d is determined by the velocity of the striker v_0 , the length of the input bar l , and the shape of the input pulse. The gap is set such that when the reflected tensile wave reaches the impact end of the input bar, the flange is in contact with the reaction mass. The reflection of the reflected wave at the impact end leads to a compressive wave. Without a momentum trap, this wave will load the sample one more time while, with the momentum trap, the reaction mass will stop the compressive stress wave from moving toward the sample. As a result, the sample will be loaded only once by the original incident wave.

3. Dynamic compression

Dynamic compression is the most common test using the SHPB. The stress and strain rate can be derived as (Kolsky, 1949):

$$\begin{cases} \dot{\varepsilon}(t) = (v_2 - v_1)/l_0 = C(\varepsilon_i - \varepsilon_r - \varepsilon_t)/l_0 = -2C\varepsilon_r/l_0 \\ \sigma(t) = (P_1 + P_2)/(2A_0) = AE(\varepsilon_i + \varepsilon_r + \varepsilon_t)/(2A_0) = AE\varepsilon_t/A_0 \end{cases}$$

where l_0 is the length of the sample and A_0 is the initial area of the sample. We invoked the stress equilibrium condition (i.e., $P_1 = P_2$ or $\varepsilon_i + \varepsilon_r = \varepsilon_t$) for the last step of the derivation.

Split Hopkinson Pressure Bar (SHPB) Tests on Rocks (cont.)

Here we discuss the issue of length-to-diameter ratio of the cylindrical compression specimen. For the standard SHPB method, the recommended length-to-diameter ratio (LDR) is from 0.5 to 1 (George and Gray, 2000). However, to avoid end effects, users normally take LDR as 2 or larger in static compression tests. In dynamic tests, a shorter sample facilitates dynamic stress equilibrium and is thus preferred. We tested Laurentian granite with the LDR being 0.5, 1.0, and 1.5 respectively. The results are summarised in Fig. 4. The sample ends were lubricated with vacuum grease. The results show that, with lubrication, a LDR of 0.5 is good enough to minimise the end effect in dynamic tests. We can also see the rate dependence of material strength from the data.

4. Dynamic tension

The BD specimen in the SHPB system is shown schematically in the insert of Fig. 5, where the sample disc is sandwiched between the incident bar and the transmitted bar. Provided a quasi-static state has been achieved in the sample during the test, the dynamic tensile strength is determined by the following equation (Iqbal *et al.*, 2008):

$$\sigma_t = \frac{2P_f}{\pi DB}$$

where σ_t is the tensile strength, P_f is the load when the failure occurs, D is the disc diameter, and B is the disc thickness. Under a quasi-static state, P_f

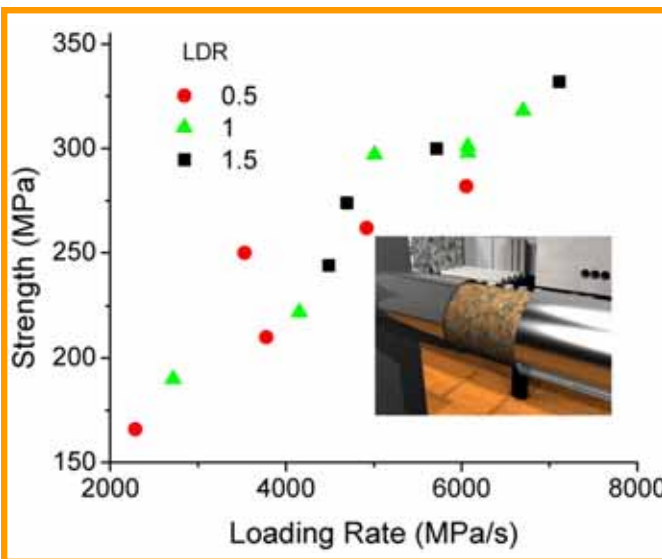


Figure 4. Effect of length to diameter ratio on compressive strength measurements with the SHPB.

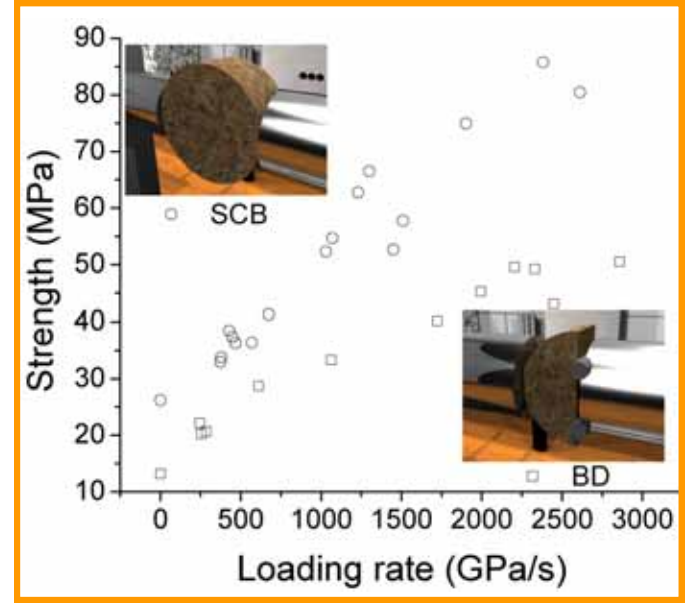


Figure 5. Rock tensile strength measured using the BD and SCB methods in the SHPB system

coincides with the maximum loading of the sample (i.e. P_2). The rate dependence of the rock tensile strength is demonstrated.

The semi-circular bend specimen in the SHPB system is shown schematically in the insert of Fig.5. Provided a quasi-static state has been achieved in the sample during the test, using a dimensional argument, the equation for calculating the tensile stress at O is (Dai *et al.*, in press):

$$\sigma(t) = \frac{P(t)}{\pi BR} \cdot Y(S/2R)$$

where $P(t)$ is the time-varying load recorded in the test, S is the span of the supporting pins and R is the radius of the disc. The dimensionless stress $Y(S/2R)$ can be calibrated using finite element analysis. The flexural tensile strength σ_f is taken as the maximum tensile stress in the history of $\sigma(t)$ and the corresponding loading rate is measured from the slope of the pre-peak linear portion of the curve. The reason why strengths measured using the SCB method are higher than those by the BD one is explained by Dai *et al.* (in press).

5. Dynamic fracture

Based on the ASTM standard E399-06e2 for a rectangular three-point bending sample (2002), we propose a similar equation for calculating the

stress intensity factor for mode-I fracture in the current SCB specimen:

$$K_I(t) = \frac{P(t)S}{BR^{3/2}} \cdot Y\left(\frac{a}{R}\right)$$

where a is the crack length and $P(t)$ is the time-varying loading force. The dimensionless geometric function $Y(a/R)$ depends on the crack geometry, and can be calculated with a standard finite element software package (e.g., ANSYS). The schematic of the SCB in the SHPB is shown in Fig. 6. The fracture toughness K_{IC} is obtained at the maximum load. The fracture toughness is shown to be rate dependent.

Provided a quasi-static state of the specimen has been achieved during the SHPB test with pulse shaping, the initiation fracture toughness K_{IC} of the CCNBD specimen is determined by the ISRM suggested method (Fowell *et al.*, 1995):

$$K_{IC} = \frac{P_{\max}}{B\sqrt{R}} Y_{\min}^*$$

where P_{\max} is the measured maximum load, B and R are the thickness and the radius of the disc respectively, Y_{\min}^* is the minimum value of Y^* , and Y^* is the dimensionless SIF and can be determined in advance by numerical calibrations accordingly. We can see from Fig. 6 that the fracture toughness obtained from the dynamic SCB and dynamic CCNBD methods are consistent.

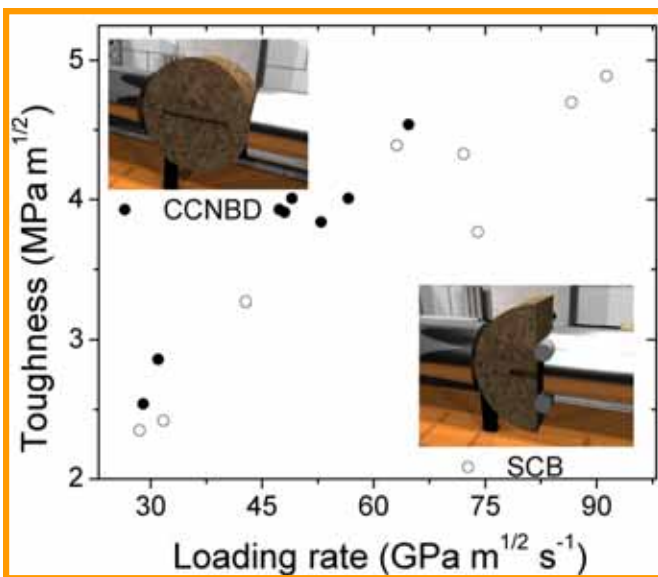


Figure 6. Rock fracture toughness measured using SCB and CCNBD methods in the SHPB system

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Large Diameter SHPB Tests with a Special Shaped Striker

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1. Introduction

The SHPB (Split Hopkinson Pressure Bar) has been a popular and promising experimental technique for the study of the dynamic behaviour of metal materials because of its easy operation and relatively accurate results, using three basic assumptions:

- (a) the waves propagating in the bars can be described by one-dimensional wave theory;
- (b) the stress in the specimen is uniform; and
- (c) the specimen inertial effect and the friction between specimen and bars is negligible.

Due to the advantages of the SHPB in dynamic tests, the technique was imported into the studies of brittle materials, such as rock, ceramic and concrete. However, because of the brittle and heterogeneous characteristics of rock-like materials, the technique had the following problems:

- ① the difficulty of stress uniformity and equilibrium in the specimen;
- ② the premature failure of the specimen before its stress equilibrium;
- ③ high oscillation of the incident wave; and
- ④ difficulty in ensuring the specimen deformation at a constant strain rate.

For the above four problems, problem ① determines the applicability of the SHPB for rock-like materials. Problem ② relates to the usability of test results. Problems ③ and ④ affect the accuracy of the test results. Focusing on these problems, much research has been carried out (Frantz *et al.*, 1984; Frew *et al.*, 2002; Xia *et al.*, 2008; Li *et al.*, 1994, 2002, 2005, 2008).

Here the 3S method (Special Shaped Striker) is elaborated, including the half-sine wave conception, special shape striker design, test applications, etc. Furthermore, improvements to the SHPB for conducting rock mechanics research serving deep underground projects are introduced.

2. Advantage of half-sine wave for large diameter SHPB tests

For rock material, with low wave velocity, the stress equilibrium of a specimen is usually reached after several reflections of the wave in a specimen. This implies that, if a steeply rising incident wave like a rectangular wave is applied to the specimen, the stress at the incident end of

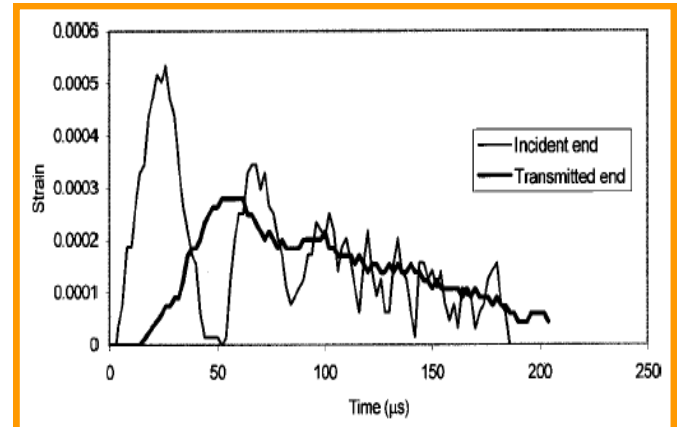


Figure 1a: Rectangular incident wave

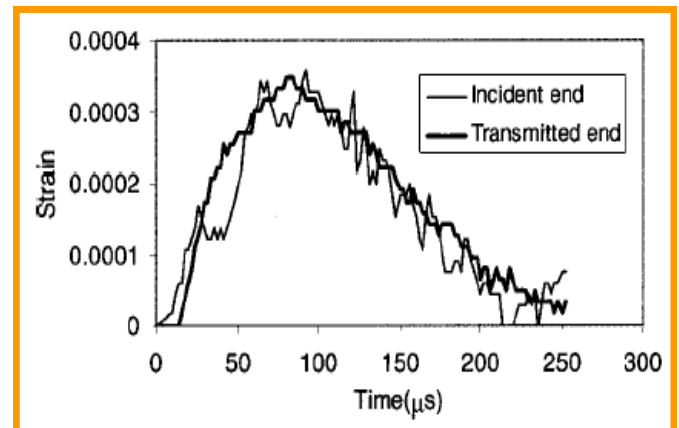


Figure 1b: Half-sine incident wave

specimen (i.e. near the input bar) will increase abruptly to be high enough to cause material failure, while the other end of the specimen (transmitted end) may have no stress disturbance.

Fig. 1 shows typical stress histories at both ends of the specimen with rectangular and an approximate half-sine wave with the 3S method. It can be seen that the case with the half-sine wave provides better stress equilibrium during the specimen deformation – while the stress in the specimen subjected to the rectangular wave shows great deviation at the two ends during specimen deformation and failure, which violates the assumption for the SHPB technique.

According to the P-C equation, the incident bar, transmitting bar and absorbing bar are all cylindrical rods with a dispersion effect. A rectangular wave can be decomposed into series of harmonic wave components as in Fig. 2 (Li and Gu, 1994). The component waves with different frequencies will travel with different individual velocities.

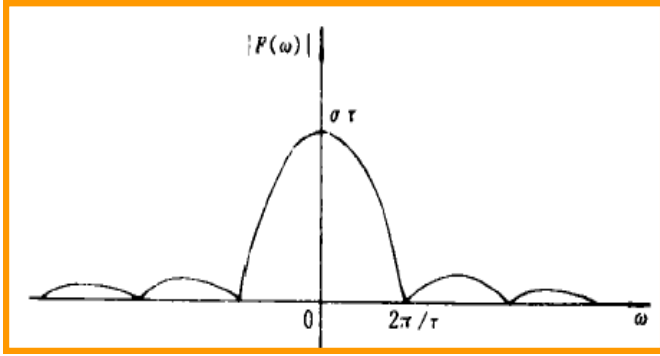


Figure 2: Frequency components of rectangular wave

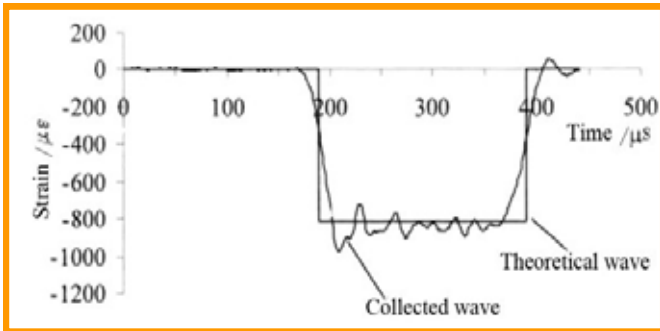


Figure 3: Oscillation of rectangular wave for dispersion

Finally, the original rectangular wave would be stretched and distorted, i.e., the wave oscillation appears (Fig. 3). More severely, the oscillation of the incident wave triggers oscillation in the reflected wave and transmitted wave correspondingly. Then, the test results of the SHPB, calculated with incident, reflected and transmitted waves, will not be valid.

On the other hand, a sinusoidal wave has a simple frequency which will travel at one determined velocity. Fig. 4(a) shows the simulation results of signals along an elastic rod with rectangular and half-sine wave incident waves. It can be seen that there is no dispersion for the half-sine wave travelling through a long bar. Also, wave dispersion from a non-sinusoidal wave can lead to non-uniform stress at the bar section when the bar diameter is large. Simulations with rectangular, triangular and half-sine waves along a thick bar showed that the stress distribution at the middle section of the bar is different in the three cases, as shown in Fig. 4(b). A half-sine wave gives a uniform stress distribution and demonstrates its advantage once again.

Furthermore, recent researches have shown that a half-sine wave can lead the specimen to deform at a constant strain rate which is vital for tests of rate sensitive materials. This can be found in the later part with the experimental results.

3. Generating the half-sine wave by the 3S method

In the practices of drilling, piling etc., different impacting tools will produce different waveforms. This indicates that the waveform has a relation with the striker geometry. This led to the idea that the half-sine wave can be produced by using a special shaped striker. For this purpose, Li *et al.* developed the Impact Discrete Inverse Theory. This theory can provide the 2-D striker geometry to produce any required waveform.

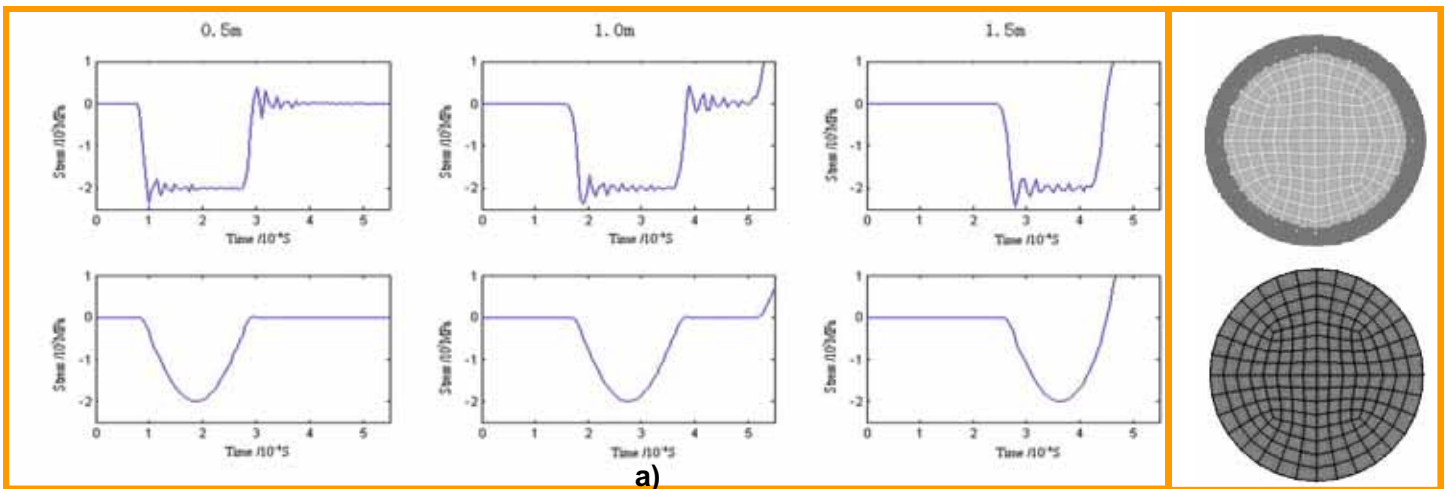
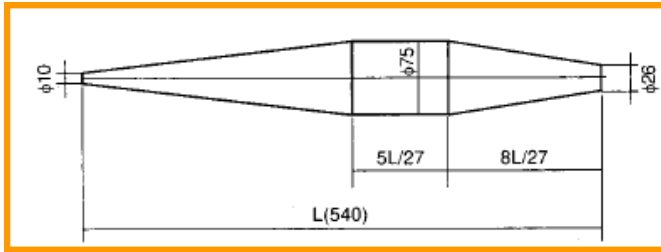


Figure 4. Dispersion effect of different incident waves in SHPB bars

a) Signals with different incident wave b) Stress distribution at a bar section for different waves

Large Diameter SHPB Tests/Special Shaped Striker (cont.)



a) Geometry of striker by inverse theory



b) 3D profile of striker by FE and NNW

Figure 5. Typical profiles of striker to produce an approximate half-sine wave

Fig. 5(a) shows one of the simplified striker geometries fabricated to produce half-sine waves.

Recently, in order to take into account 3-D factors like material damping, frictional effect, dispersion, etc., a method combining FE (Finite Element) and NNW (Neural Network) was developed to make the 3S method have more accuracy, Fig. 5(b).

4. Application of special shaped striker in SHPB tests

For rock material, its dynamic strength increases with strain rate following an exponential law. The static strength of rock with a strain rate of 10^{-5} - 10^{-2} /s can be obtained with MTS and INSTRON hydro-servo-controlled machines. For rock tests with loading rates of 10^{-2} /m - 10^0 /s, various pneumatic driven machines were invented (Zhao *et al.*, 2000). For higher strain rates exceeding 10^3 /s, gas guns have been successfully deployed to measure the response of rocks. However, for an intermediate loading rate of 10^0 - 10^3 /s, which is common in drilling and boring, there is a scarcity of experimental equipments and available data for refer-

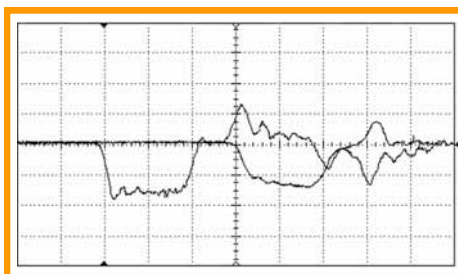
ence. With the constructed large diameter SHPB, the intermediate loading rate can be obtained successfully (Li and Lok, 2005). With the half-sine wave by the 3S method for a large diameter SHPB, many rock experiments at intermediate loading rates have been conducted (Li and Lok, 2002, 2005; Zhou and Li, 2006).

Fig. 6 gives typical test signals and the obtained stress-strain curves for rock subjected to half-sine and rectangular incident waves. The flat reflective segment of the half-sine case indicates that the rock deforms at the constant strain rate. The smooth evolution of the stress-strain curve for the half-sine case also shows that the half-sine wave eliminates greatly the wave dispersion and oscillation.

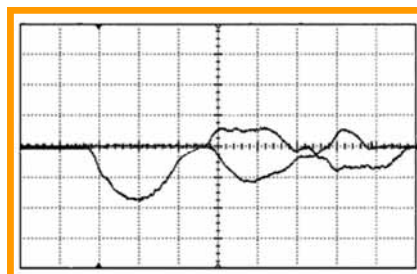
Rock material is usually heterogeneous with inner defects and grains, so its strength always shows a size effect. The size effect in static strength has been widely studied, while there is still little known about the dynamic size effect – because of its complexity. With the special shaped striker on the SHPB with bar diameters of 22 mm, 36 mm and 75 mm, the dynamic size effects for granite, siltstone and limestone have been investigated (Li and Hong, 2008). Fig. 7 gives the different sized strikers by the 3S method, and Fig. 8 presents the size effect for granite under different strain rates.

5. Conclusions

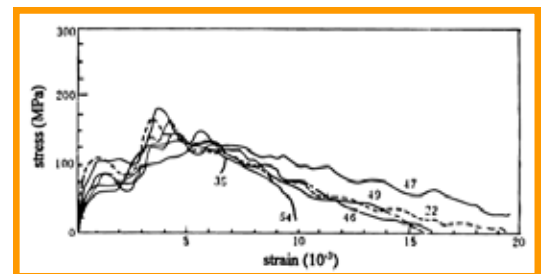
Improvement of the SHPB by using special shaped strikers has been developed. The advantages of a special shaped striker or half-sine wave have been elaborated with comparison with a rectangular wave. The development methods for the special shaped striker were introduced. Test results with special shape strikers were summarized and some new developments for the SHPB 3S method have been achieved.



a) Rectangular incident waves



b) Half-sine incident wave



c) Complete stress-strain curves

Figure 6. Test signals and obtained stress-strain results with rectangular and half-sine waves



Figure 7. Strikers for dynamic size effect research

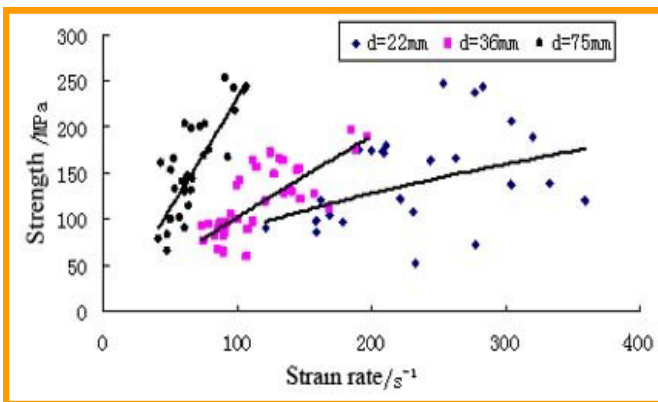


Figure 8. Size effect for granite under different strain rates

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FEM/DEM Simulation of Dynamic Brazilian Tests

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1. Introduction

The rock heterogeneity, together with fracture and fragmentation processes, limit the applicability of continuum-based models to address rock engineering problems and in particular those that involve dynamic failure of the rock. In the past, various discontinuum approaches have been developed to try to overcome these limitations. However, none of them is fully able to properly model the entire loading and failure process including the transition from continuum to discontinuum that is typical of fracturing and fragmentation processes in rock.

To overcome these limitations Munjiza (2004) proposed a new hybrid finite discrete element method (FEM/DEM). In FEM/DEM each discrete element is discretised into finite elements, meaning that there is a finite element mesh associated with each discrete element. Thus, continuum behaviour is modelled through finite elements, while discontinuous behaviour is analysed by discrete elements.

In the context of the combined finite-discrete element method, the transition from continua to discontinua is achieved through a fracture and fragmentation processes (Munjiza, 2004). A combined single and smeared crack model is implemented in the FEM/DEM code used for this study. In this model, a typical stress-strain curve is divided into two sections. The first part, corresponding to strain hardening prior to reaching the peak stress (i.e. tensile strength), is implemented through the constitutive law, as in any standard finite element method. The second part, related to the post-peak behaviour, refers to strain-softening and is formulated in terms of stress and displacements (Munjiza, 2004; Andrews *et al.*, 1999).

The softening stress-displacement relation is modelled through a single crack model. A bonding stress is generated by the separation of the edges. This stress is assumed to be a function of the size of separation (or crack opening). Further details can be found in the book “The combined finite-discrete element method” (Munjiza, 2004).

2. Experimental data

In this communication, we present the results of an exercise conducted to numerically simulate the failure of a disc specimen under dynamic indirect tensile stress. The basis for the model stems from Dr. Xia's laboratory work, which utilised the Split Hopkinson Pressure Bar (SHPB) apparatus to carry out dynamic testing on Brazilian disc specimens for the measurement of indirect tensile stress at failure.

The SHPB testing was carried out on two Barre Granite disc specimens at gas gun pressures of 49 kPa and 105 KPa. The test specimens, placed in the SHPB system between the incident and transmission bars, were loaded through a stress pulse generated by the impact of the striker bar against the long incident bar (Figure 1). The assessment of the specimen stress and strain from the SHPB testing follows 1-D stress wave theory.

The strain gauges attached to the incident and transmission bars recorded the strain amplitude (converted from voltage) and time duration of the passing stress waves at 0.2 ms increments and allowed calculation of the incident (σ_i), reflected (σ_r), and transmitted (σ_t) stresses. The particle velocity at the bar/sample interface was then calculated and used in the numerical simulations as a loading condition in the model.

3. Numerical modelling

The numerical modelling was carried out using the FEM/DEM research code currently under development at the Geomechanics Group at the University of Toronto. The FEM/DEM is a two di-

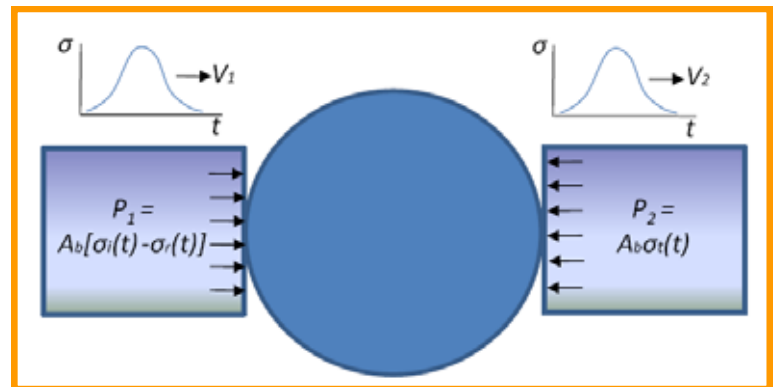


Figure 1. Loading configuration for the SHPB Brazilian tests

mensional combined finite element-discrete element method research code that evolved from the original Y-Code developed by Munjiza (2004). The model configuration showing the nodal and element distribution for the Brazilian disc, and arrangement of loading platens is shown in Figure 2. The model was scaled to the approximate true dimensions of the SHPB disc (40 mm diameter) and transmission bar diameter (25 mm). The average element size was 1 mm, which resembles the average grain size of Barre Granite (0.9 mm). The platen was modelled as an extremely stiff elastic material in order to reduce elastic deformations and rebound.

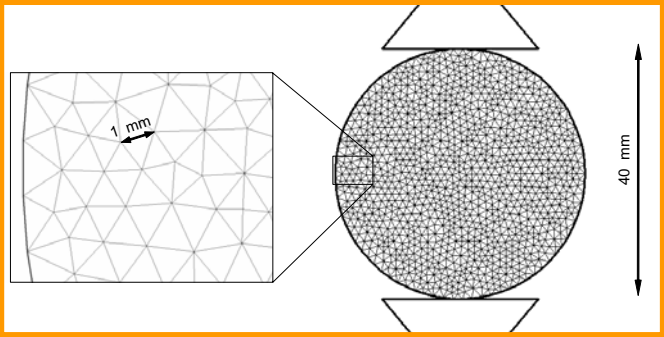


Figure 2. Mesh used for simulating the SHPB Brazilian tests model

The loading configurations used in the model reflected accurately the dynamic loading conditions measured during the laboratory SHPB tests. In the SHPB test, the sample is loaded through the transfer of the stress impulse from the incident bar into the sample. The reactionary stress pulse in the transmission bar, more or less equal to the incident stress minus the reflected stress, represents the total stress imparted to the specimen. Consequently, the ultimate load imparted to the specimen is more or less symmetrical between the two sample interfaces (as shown in Figure 3). The rate of stress transfer is associated with the load rate, dependent on the amplitude and duration of the transmitted stress wave.

As mentioned earlier, in order to reproduce the SHPB test loading conditions for the Barre Granite Brazilian disc specimens in our numerical model, we input the measured bar velocities to the loading platens. The resulting loading rates calculated both in the sample and loading platens were reasonably similar to the loading rates measured

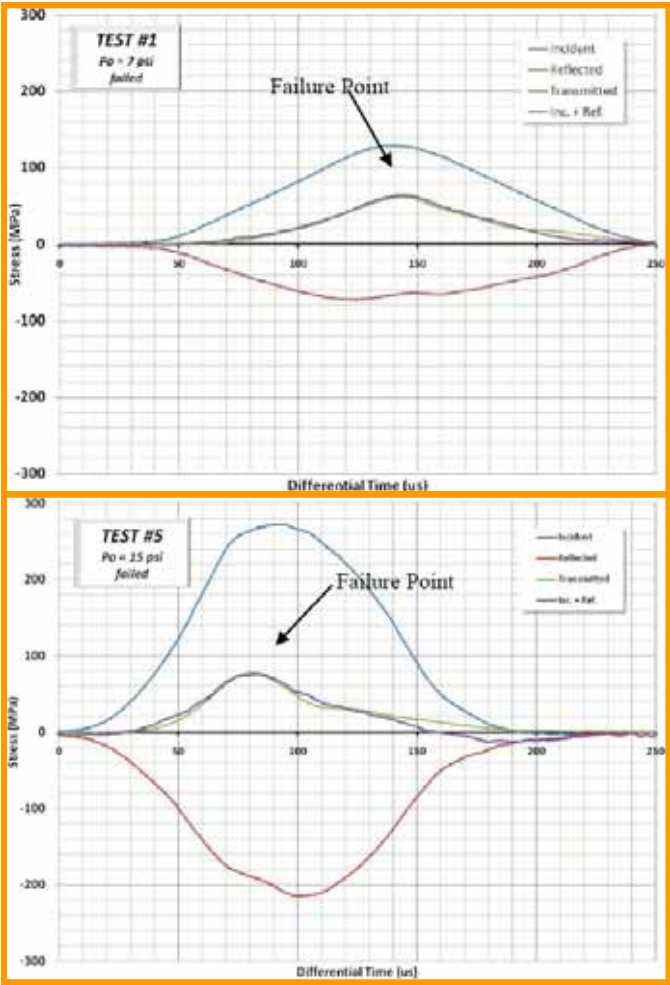


Figure 3. Incident, reflected, transmitted and increment + reflected stress wave components measured for (A) Test 1 ($P_o = 49$ kPa), and (B) Test 5 ($P_o = 105$ kPa)

in the laboratory. The fractured disc specimens obtained in the laboratory (Figure 4) showed substantial damage at the loading points of the samples, possibly related to crushing or shearing of the rock. Secondary cracking was also visible in the second test (#5, $P_o = 105$ kPa) considered in this communication. Interestingly, our FEM/DEM simulations were able to reproduce the observed fracture patterns, including the crushing at the loading points and the propagation of radial secondary cracking in sample #5 (Figure 5).

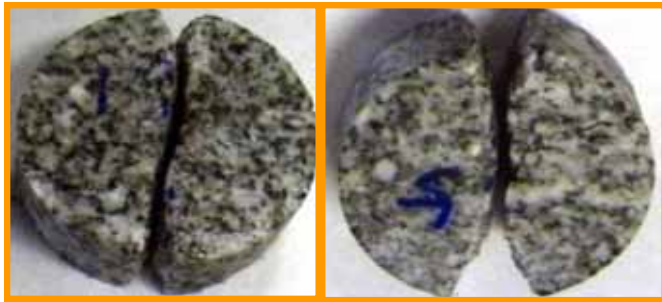


Figure 4. Left: Failed sample for Test 1 ($P_0 = 49$ kPa). Right: for Test 5 ($P_0 = 105$ kPa)

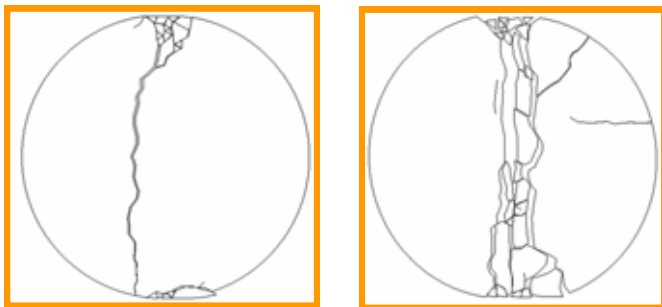


Figure 5. FEM/DEM fracture pattern calculated for Left: Test 1 ($P_0 = 49$ kPa), Right Test 5 ($P_0 = 105$ kPa)

The relatively simple modelling exercise presented in this report shows good agreement between simulation results and laboratory observations. The above results show the considerable potential in using FEM/DEM to realistically simulate the dynamic response of rocks and, more broadly, of geomaterials.

In an attempt to test the ability of our FEM/DEM code to model not just laboratory tests but also more realistic rock engineering problems, we have simulated two general cases related, one to underground mining, and the other to open pit wall stability. The results presented in Figure 6 and 7 suggest that FEM/DEM can model mass mining processes, from initial blasting to caving progression (see Figure 6 for a qualitative example), and also reproduce failure processes associated with a rock slope, accounting for the influence of geology, preexisting faults and joints on the wall stability (see Figure 7 for a qualitative example).

Looking in more detail at the mass mining model (Figure 6), the results clearly show (i) the propagation in time of the cracks upward to the free surface (caving), (ii) the progressive fragmentation of the rock mass, and (iii) the complex

interaction processes during flowing of broken rocks including secondary fragmentation.

On the other hand, in Figure 7 it is interesting to notice how the FEM/DEM model reveals, as emergent properties, the different behaviour modes that are observed during slope failure processes, such as the formation of a localised failure plane that develops into a thin fractured layer (shear zone) and plays a major role in the final catastrophic slope failure.

4. Conclusions

In conclusion, the results presented in this short communication show the capability of the FEM/DEM hybrid method to realistically reproduce SHPB dynamic testing on Brazilian disc specimens for the measurement of indirect tensile stress at failure. We have also shown how we can extend the use of the code to model progressive failures that are everyday observed in the mines around the world.

These results suggest that, in a not too far future, an FEM/DEM code could be applied to quantitatively model large-scale complex engineering processes such as mass mining, or complex slope stability problems. The reader should be aware that, at the present stage, the major limiting factors for the FEM/DEM code are the computational power required for solving large models (with millions of elements or more) and the fact that most of the processes related to rock engineering problems need three dimensional solutions. The current development of a cluster version of the 3D-FEM/DEM code will likely overcome those limitations and provide all engineers with a reliable predictive tool ready to be used in practice.

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Editor's Note: In addition to this article, Dr Grasselli has also provided guidelines on the use of computer simulations in rock.

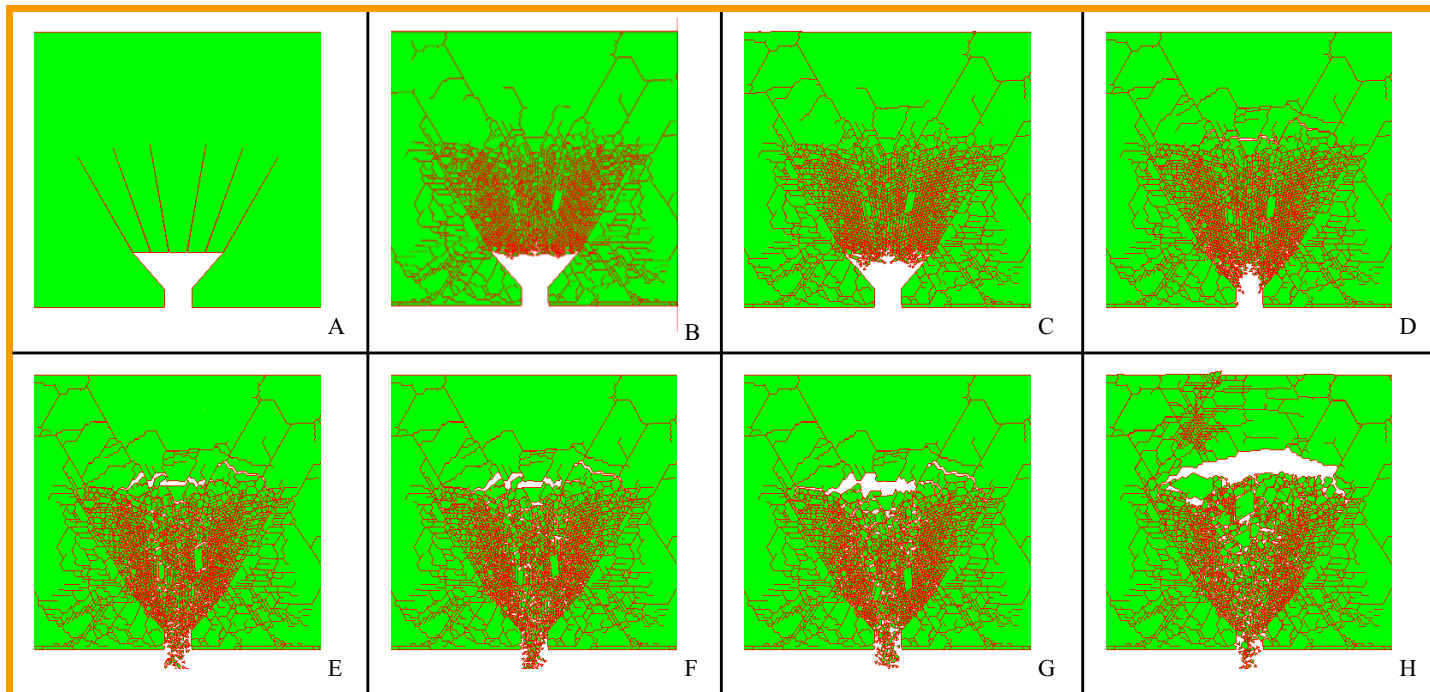


Figure 6. FEM/DEM numerical simulation of the blasting fracturing and successive primary and secondary fragmentation associated with the caving process (Model provided by Mahabadi and Lukas, 2009)

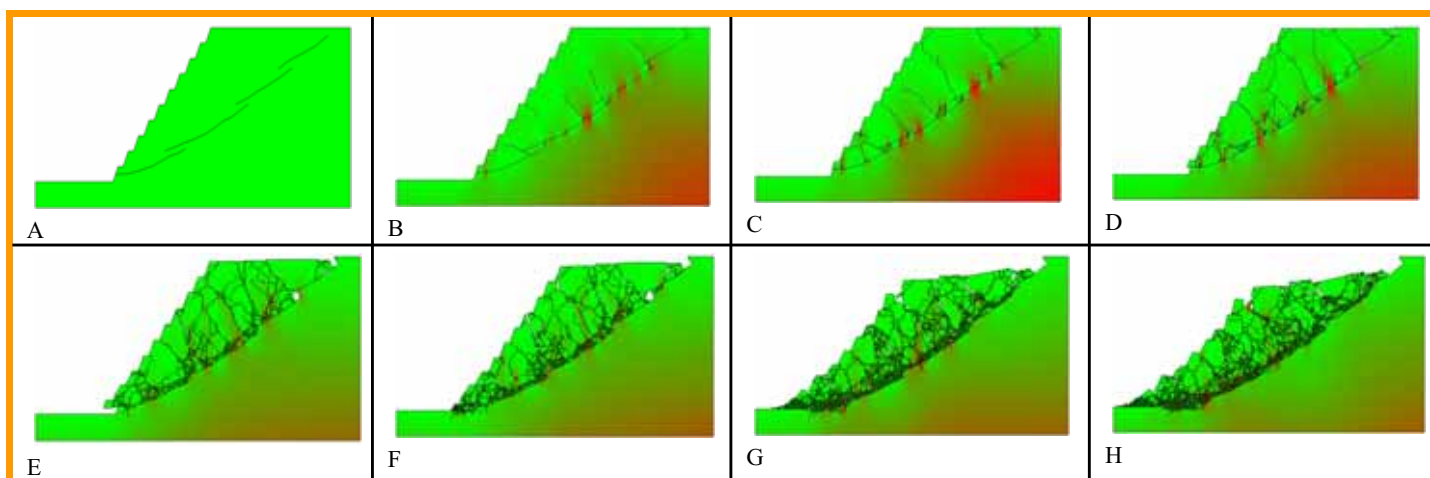


Figure 7. Numerical modeling of the progressive failure process for a rock slope (model provided by Piovano, 2009)

Suggestions for ensuring that numerical models adequately represent rock reality

- A protocol should be developed to ensure that numerical models adequately represent the rock reality.
- Auditing the codes is required to ensure that they contain the necessary variables, parameters and coupling models.
- A check is required so that appropriate information is input correctly into the codes.

- There needs to be key test case data sets for checking numerical codes – so that material and sample geometry heterogeneity are taken into account.
- Also, a series of benchmarks (analytical solutions and highly controlled experimental tests) should be developed.
- The use of advanced techniques (micro CT, super-fast cameras, etc.) to acquire new types of data to be used as input and source of verification for the codes is encouraged.

Continued on page 87

Constraining Paleoseismic Peak Ground Acceleration

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1. Introduction

Seismic hazard is defined in terms of the probability of exceeding a certain ground motion in a specific area, and is typically discussed in terms of Peak Ground Acceleration (PGA). Predicted PGA values for specific regions are commonly reported in national seismic building codes and therefore PGA is used extensively in earthquake engineering practice throughout the world. A new method to constrain expected earthquake PGA values, by back analysis of finite block displacements in historic masonry structures, is presented here. The preserved and damaged structures are first mapped in great detail in the field and, on the basis of the acquired geometrical data, a mesh of discrete blocks is generated numerically, representing the presumed undeformed structural configuration. Then, the discrete block system is loaded numerically by dynamic input functions until the deformed configurations that best fit the preserved damaged configurations in the field are obtained. As a first order approximation, harmonic, sinusoidal, input acceleration functions are used so that the most likely amplitude (PGA), as well as frequency and duration of the input motion, are obtained directly as a result of the analysis. The analysis can be repeated with real earthquake records to further constrain the dynamic motion parameters.

2. Validation of the numerical approach for dynamic simulations

The numerical approach used in this study is the implicit, discrete, numerical Discontinuous Deformation Analysis (DDA) method [1]. Before results of numerical analysis are presented, it is important to discuss the significance of performing numerical code validations using existing, or originally developed, analytical solutions for dynamic problems. Hatzor and Feintuch [2] and later Kamai and Hatzor [3] demonstrated the ability of DDA to accurately compute the dynamic displacement of a block on an incline subjected to an harmonic input function applied at its centroids. Kamai and Hatzor [3] proceeded to study the dynamic response of a prismatic block subjected to induced dynamic displacements in an underlying block and found high accuracy be-

tween analytical and DDA results. Finally Yagoda-Biran and Hatzor [4] studied the rocking motion and eventual collapse of a slender column subjected to harmonic loading functions applied at its centroids and found excellent agreement between the analytical ([5]) and DDA solutions. The interested reader is encouraged to consult the cited references to learn more about the details of the validation studies.

3. Sliding of a keystone in a Roman arch



Figure 1. Location of studied sites (red dots)

Mamshit is the last Nabatean city built in the Negev on the trade route between Petra, Hebron, and Jerusalem during the Roman period (Figure 1). A unique structural failure is noticed in a tower at the corner of the Eastern Church at the site, where a key stone has slid approximately 40 mm downwards out of a still standing semi-circular arch (Figure 2). Numerical analysis is performed on a block mesh containing the arch, embedded in a masonry wall (Figure 3), similar to the structural configuration in the field.



Figure 2. Preserved keyblock displacement in a Roman period arch at Mamshit (for location see Figure 1)

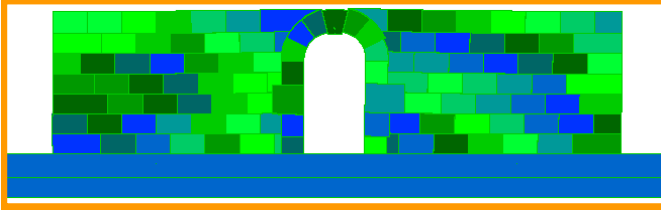


Figure 3. Simulated keystone deformation with DDA (after [3])

To constrain the paleo-seismic PGA that could have caused the observed damage, we subjected the mesh to several harmonic input functions with variable frequencies and amplitudes. Figure 4 shows the results of such an approach for constraining PGA for a fixed value of frequency (1 Hz). The dynamic loads were applied to the centroids of all the blocks in the mesh simultaneously using a horizontal component of motion only. Inspection of Figure 4 reveals that, to obtain the observed 40 mm vertical displacement of the keystone, a PGA value of 0.5 g would have been required. Under lower PGA values, vertical displacement is lower than observed in the field. Subjecting the structure to higher PGA values, however, does not necessarily result in increased vertical motion, as can be seen from the obtained response of the structure to PGA of 0.8 g.

By running a series of such analyses, once for a fixed value of frequency, for seeking best fit PGA, and then for a fixed PGA, for seeking best fit frequency (see [3]), we concluded that the threshold PGA that can be inferred for this site is PGA = 0.5 g with a frequency of $f = 1.5$ Hz. Re-

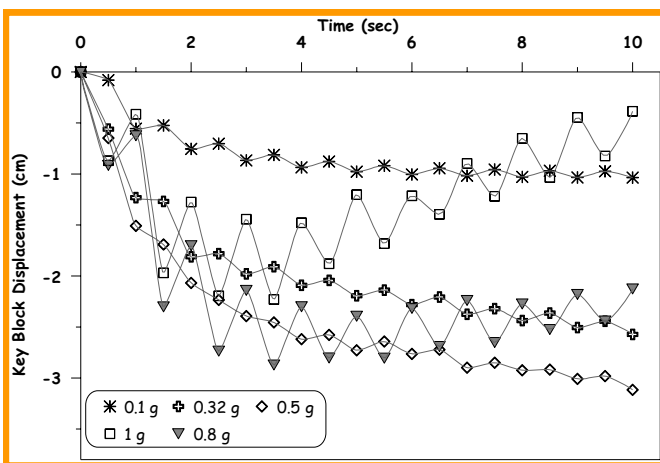


Figure 4. DDA results for the keystone at Mamshit (after [3]): Influence of the input motion amplitude on vertical keystone displacement ($f = 1$ Hz)

garding the duration of the motion, it can be seen in Figure 4 that the structure attains a new equilibrium after a certain period of time, so that repeated cycles of input motion do not necessarily result in increased values of downward displacement of the keystone. We conclude that, for the obtained dynamic parameters here, the duration of motion must have been equal or greater than 10 seconds.

4. Pillar collapse in a Byzantine church

Susita, or by its Greek name *Antiochia-Hippos*, was founded during the Hellenistic period, after 200 BC. The S-E church at Susita, the collapsed columns of which are analyzed here, was built during the Byzantine period. One row of collapsed columns that originally supported the roof can clearly be seen today. The collapsed columns rest parallel on the ground surface (Figure 5). Susita is believed to have been destroyed during the large earthquake of 749 AD. Some of the columns that have collapsed are broken, most columns are displaced by some

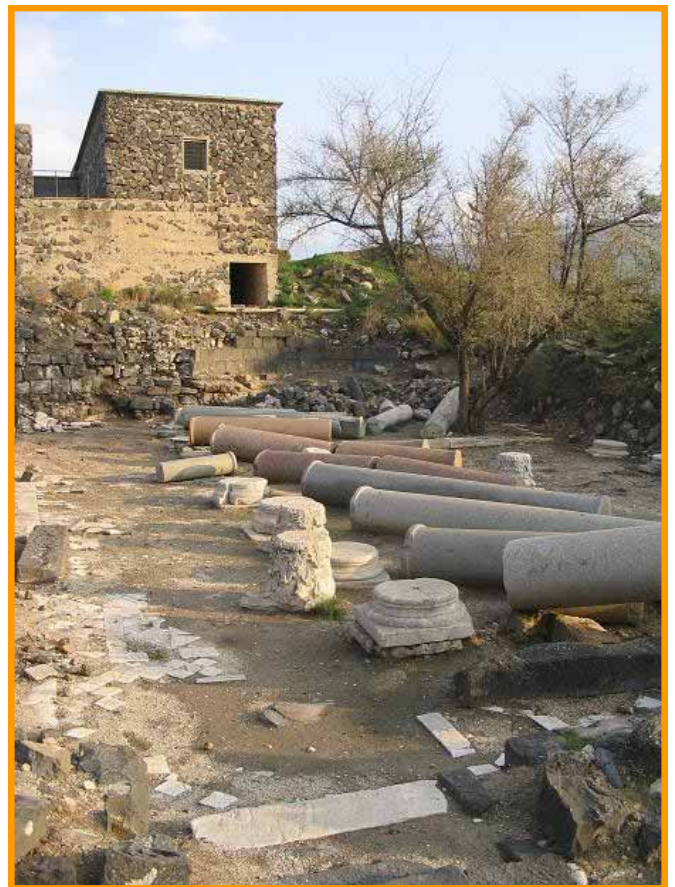


Figure 5. The series of collapsed columns preserved at the Susita site

Constraining Paleoseismic Peak Ground Acceleration (cont.)

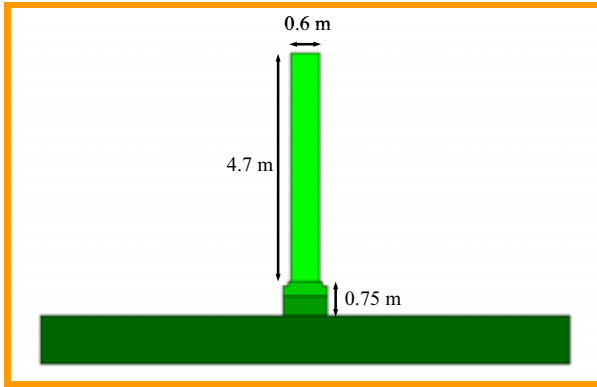


Figure 6. DDA mesh used to model column response to shaking, after Yagoda-Biran [6]

finite distance from their bases, and some columns have rolled on the ground after the collapse.

The DDA block system used in this research for a typical Susita column is presented in Figure 6. The parameter for which the numerical analysis is most sensitive, the normal contact spring stiffness, is found by iterations using the analytical solution [5] at the instantaneous response stage when only free oscillations are obtained under an

input peak acceleration value sufficiently small so as to avoid column toppling. Once optimal numerical control parameters are found, forward DDA modelling can be performed for various input motion frequencies and amplitudes.

DDA results for harmonic input functions of one and three sinusoidal cycles indicate that the required PGA for a free-standing column is frequency dependent. Since a free standing column does not possess a natural resonance frequency [7], the results obtained with harmonic sinusoidal input functions cannot be utilised to effectively constrain the driving paleo-seismic PGA. Instead, we used various earthquake records measured in similar tectonic settings for strike slip events and increased or decreased the record until insipient collapse was obtained. With this approach, we were also able to consider simultaneously horizontal and vertical components, as well as a realistic frequency content. Interestingly, the obtained results are nicely confined between $0.2 \text{ g} < \text{PGA} < 0.4 \text{ g}$, as illustrated in Figure 7.

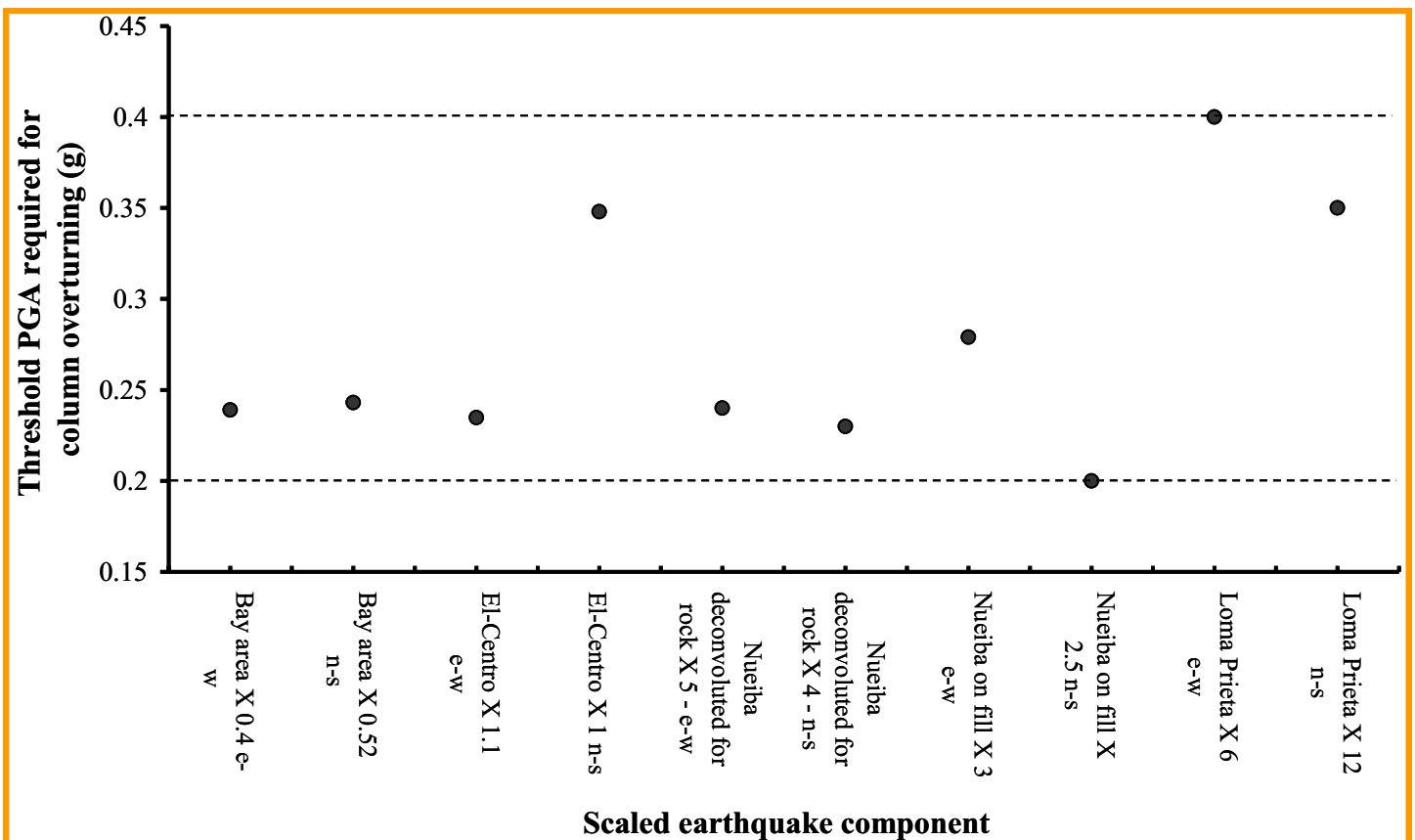


Figure 7. Threshold PGA required for column overturning – obtained by subjecting the model to 10 different earthquake records. The original records were either down-scaled or up-scaled until column overturning was obtained [after 6]

5. Summary and conclusions

The numerical DDA is used to constrain paleo-seismic PGA from back analysis of structural failures preserved in historic masonry structures. The validity of DDA in such dynamic applications has been tested extensively and results have been published elsewhere [2-4]. Two structures are analyzed: a Roman arch where the keystone displaced but the arch remained intact; and a collapsed pillar in a Byzantine church.

Dynamic modelling of the keystone displacement in the Roman arch suggests that the driving PGA was at least 0.5 g at a frequency of 1.5 Hz. The duration of shaking that was necessary to obtain the measured amount of downward displacement must have been at least 10 seconds long.

Dynamic modelling of the collapse of the Byzantine column reveals that the required PGA for toppling is frequency dependent. As a free standing column does not possess a natural resonance frequency (Housner, 1963 #676) the paleo PGA required for overturning cannot be effectively constrained using harmonic input motions.

For obtaining upper and lower bounds on the required PGA for toppling, we subjected the modelled column to a variety of real earthquake records measured in rock sites during strike slip events, as presumed to have occurred along the Dead Sea seismic zone during the failure of the analysed structure. The results thus obtained are constrained between $0.2\text{ g} < \text{PGA} < 0.4\text{ g}$.

While the presented results are preliminary, we believe that we have presented a method to assess seismic hazard in earthquake prone regions of the earth where structural failures have been preserved in masonry structures. PGA values thus obtained can be used in conjunction with national seismic building codes that predict expected PGA on the basis of statistical analysis of instrumentally recorded data. This approach may be particularly important in countries where the seismic record is either short or restricted.

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The text below is continued from page 83

- We need to build a common language: i.e. the definition of terminology to be used in Rock Dynamics.
- We need to have a clear description of the modelling techniques
- We need to have a full description of all parameters to be used in the model and how to obtain them (through static and dynamic tests), as well as access to the model mesh.
- All models used should include the list of all parameters and readable input files (99% of papers with numerical models published in our literature are not verifiable since it is impossible to obtain all the information that we need to reproduce them).
- We should look at other fields such as biology where all data, once published, are available to the public.

Explosion Loading and Tunnel Response

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1. Introduction

A series of large-scale tunnel explosion tests were conducted to validate the safety design for underground ammunition storage, including the response of tunnels. While the design for measuring ground shock loading and tunnel response was relatively easy, the initial design of the test facility presented some engineering challenges in the prediction of the dynamic loading, tunnel damage assessment, and dynamic rock support for the tunnel facility which was designed for repetitive explosion loading. This paper presents some results from the large-scale tests and discusses the effects of decoupling on dynamic loading and tunnel response.

2. Large-Scale Tunnel Testing

The test facility is located in Älvdalen, Sweden, site of the existing Klotz Group tunnel (Chong *et al.*, 2002). It was constructed in a rock mass consisting of mostly red porphyry with some grey granitic intrusions. The fresh intact rock has uniaxial compressive strengths of 200-250 MPa. The rock mass quality is considered 'good' with average Q values of 15-20.

The test facility consists of a detonation chamber connected by a series of tunnels. Adjacent and parallel to the chamber is a slot tunnel at criterion separation distance ($0.6 Q^{1/3}$) to test and monitor the response of an adjacent chamber (Figure 1). The average rock cover over the chamber area is about 100 m. The chamber has a width of 8.8 m, a height of 4.2 m, and length of 33 m. The slot is 2 m wide and has the same height as the chamber. The main tunnel connecting the chamber and slot is 4.5 m. The actual separation between the chamber and slot tunnel is about 13 m based on a maxi-

imum Net Explosives Quantity (NEQ) of 10 tons of TNT.

As the tunnel was designed to last through four years of explosion testing, including fragment loading, dynamic rockbolts (Ansell, 1999) were used to support the chamber and the areas within $0.6 Q^{1/3}$ (or about 13 m) from the chamber wall. The dynamic bolts have a smooth section which allows them to detach from the grout and undergo large deformations under high dynamic loads. In the detonation chamber, plain shotcrete was applied in two layers, with a wire mesh in-between.

A total of five tests were carried out, with all detonations in the same chamber. Table 1 shows a list of the tests conducted. With the exception of Test #1, the charges for all other tests were evenly distributed in 10 tables in the chamber, with the bottom raised to about 800-900 mm above the chamber floor. This distributed charge set-up was meant to simulate real storage conditions.

Details of the tests and instrumentation are discussed in a separate paper (Chong *et al.*, 2002). This paper will only discuss results of the ground shock measurements and observations of the tunnel response.

Ground shock gauges were installed in the following locations (Figure 2):

- a horizontal hole, perpendicular to the chamber axis;
- a vertical hole, above the chamber centre; and
- along the wall of the slot tunnel, at 13m from the chamber wall.

Strain gauges were also installed on two dynamic rockbolts, installed along the middle of the slot tunnel wall.

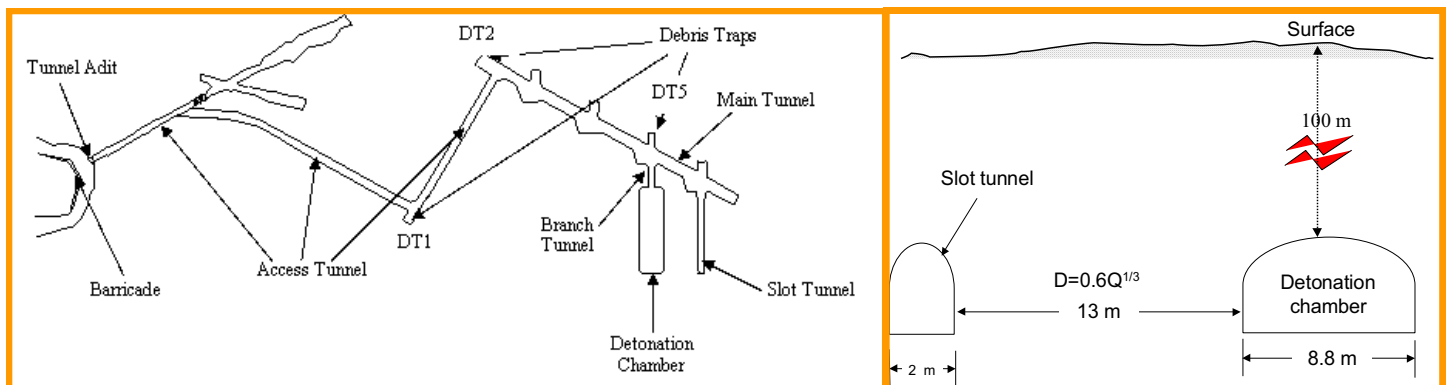


Figure: 1 Test tunnel facility layout (left) and chamber sections (right)

Table 1: Test Set-Up and Objectives

No.	NEQ (kg)	Charge Type	Objectives
1	10	Fully coupled bare charge	Ground shock calibration.
2	500	Bare charge	Bare charge test at loading density 0.5 kg/m ³ for airblast calibration
3	10,000	Bare charge	Bare charge test at loading density 10 kg/m ³ as reference test
4a	2,500	Bare charge	Bare charge test at loading density 2.5 kg/m ³ at intermediate loading density
4b	10,000	Cased munitions	Fragment loading & debris flow effects in tunnels at loading density 10kg/m ³

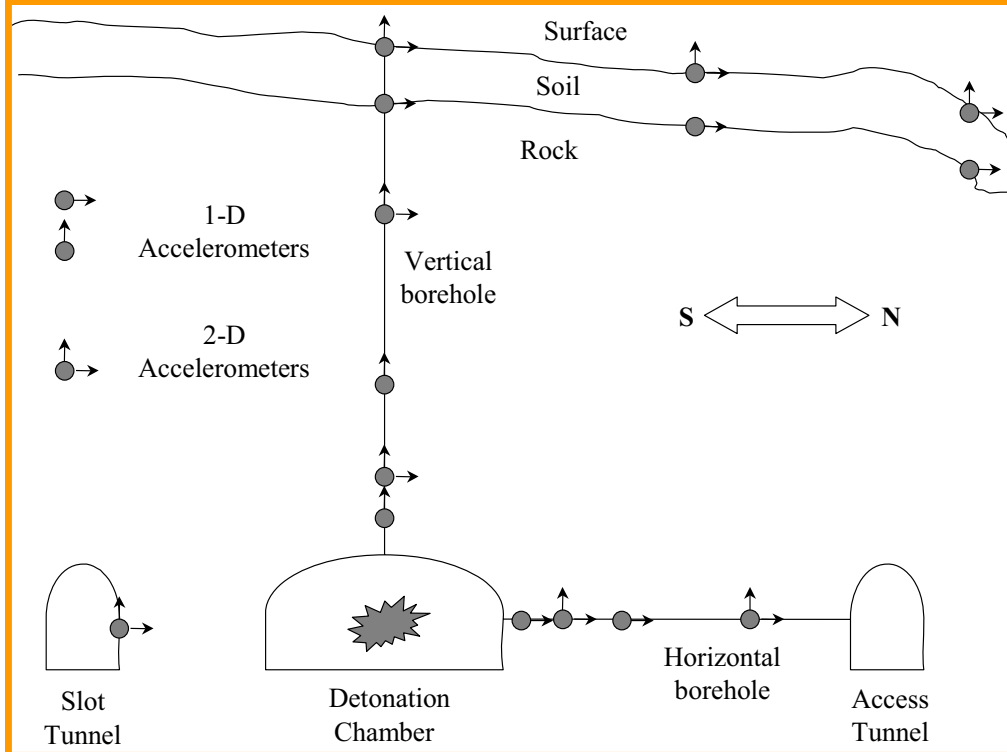


Figure 2: Sectional view of ground shock instrumentation

3. Results and observations

Based on observations after the tests, the amount of damage sustained in the tunnel system was surprisingly less than had anticipated. Figure 3 shows some photos of the chamber and the slot tunnel after the detonations.

For the 10-ton and 2.5-ton tests, ten craters of a similar size were created on the floor below the ten charges after each detonation. The ten craters of similar size also confirmed complete detonation of all charges. There was no rockfall from the roof or walls. In the 10-ton bare charge test, there were very few spots of observed spalling of the shotcrete. For the 155-mm cased charges, there were more shotcrete spalls on the chamber walls due to the directional loading of the steel fragments. Even so, no bare rock was observed in the chamber wall, except in one location near the branch tunnel, where a piece of rock fell off. The

surprisingly low damage in the chamber might be due to the ‘burned’ shotcrete resulting from Test #3, which may have converted the shotcrete into some form of sandy material. This sandy material could have acted as an energy-absorbing layer against the fragments of Test #4b, thereby limiting the tunnel wall damage.

In the slot tunnel, no damage of the shotcreted or bare wall was observed. The only exception was at a gauge hole, where the shotcrete had been damaged during drilling and subsequently dropped to the tunnel floor due to the ground shock loading. The loose material on the floor showed some movement from Test #3. All lights

and fixtures in the slot tunnel remained fully functional after the tests. The relatively small damage of the rock separation is also confirmed by the low strains recorded on the rock bolts from Test #3 (Figure 4). The calculated seismic velocities of the slot wall show an 8% reduction after Test #3 (from 4,636 m/s to 4,268 m/s) and subsequently remained unchanged. The initial change was probably due to loosening of the joints, rather than new fractures created in the rock mass. Thus, it was concluded after Test #3 that the dynamic rockbolts were not necessary due to the relatively low dynamic loads.

For Tests #3 and #4b, the average PPV recorded on the slot wall was 1.4 m/s and 0.97 m/s, respectively. Since the PPV’s are recorded on the slot tunnel wall (perpendicular to it), their values represent the reflected ground shock wave. The equivalent free field PPV at the same distance

Explosion Loading and Tunnel Response (cont.)



Figure 3: Photos of the detonation chamber and slot tunnel after Tests #3 and #4b

would be roughly one half of the recorded value. Test #4b produced a lower ground shock due to casing effects of the 155-mm shells with an equivalent TNT of 0.54 based on ground shock measurements. This casing effect is also confirmed from blast pressure measurements, which showed equivalent TNT from 0.45 to 0.67 of bare TNT (Chong *et al.*, 2002).

4. Effects of decoupling on ground shock

Results of ground shock measurements are plotted in Figure 5, along with the PPV equation for fully-coupled detonations from earlier tests conducted at the same site (Hultgren, 1987). The distance is measured from the chamber centre.

The decoupling effect can be seen clearly from Figure 5. For example, at the same scaled range of $1 \text{ m/kg}^{1/3}$, the mean peak particle velocity was 15 m/s, 1 m/s, and 0.4 m/s, for fully coupled and loading densities of 10 kg/m^3 and 2.5 kg/m^3 , respectively. The respective decoupling factor for the PPV, for loading densities of 10 kg/m^3 and 2.5 kg/m^3 are 0.067 and 0.027. In other words, at a distance of about 22 m, a 10 tonne explosion with a loading density of 10 kg/m^3 will produce only about 7% of the PPV of a fully coupled charge of the same quantity.

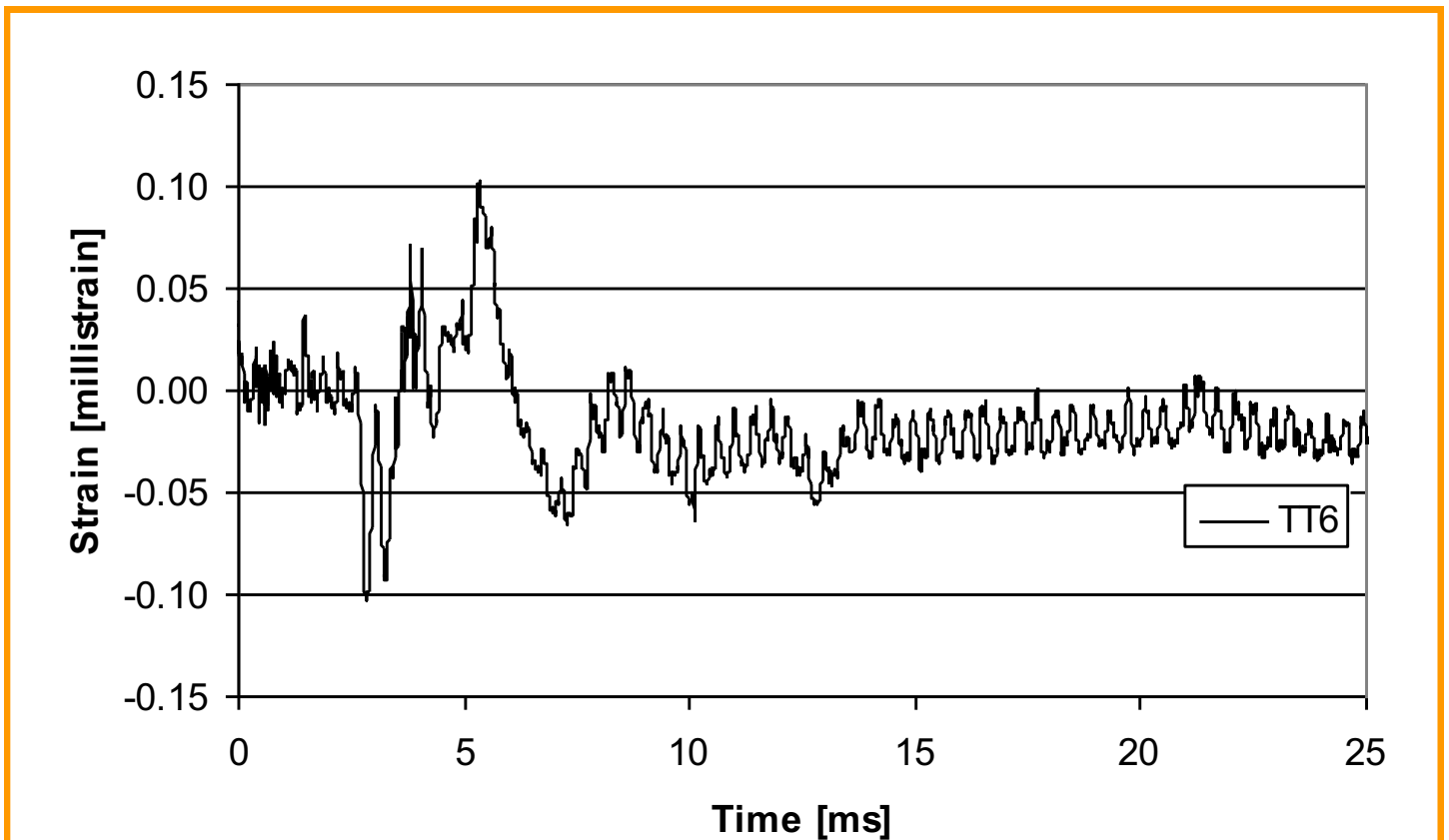


Figure 4. Dynamic strain recorded on rockbolts installed from the slot tunnel (Test #3)

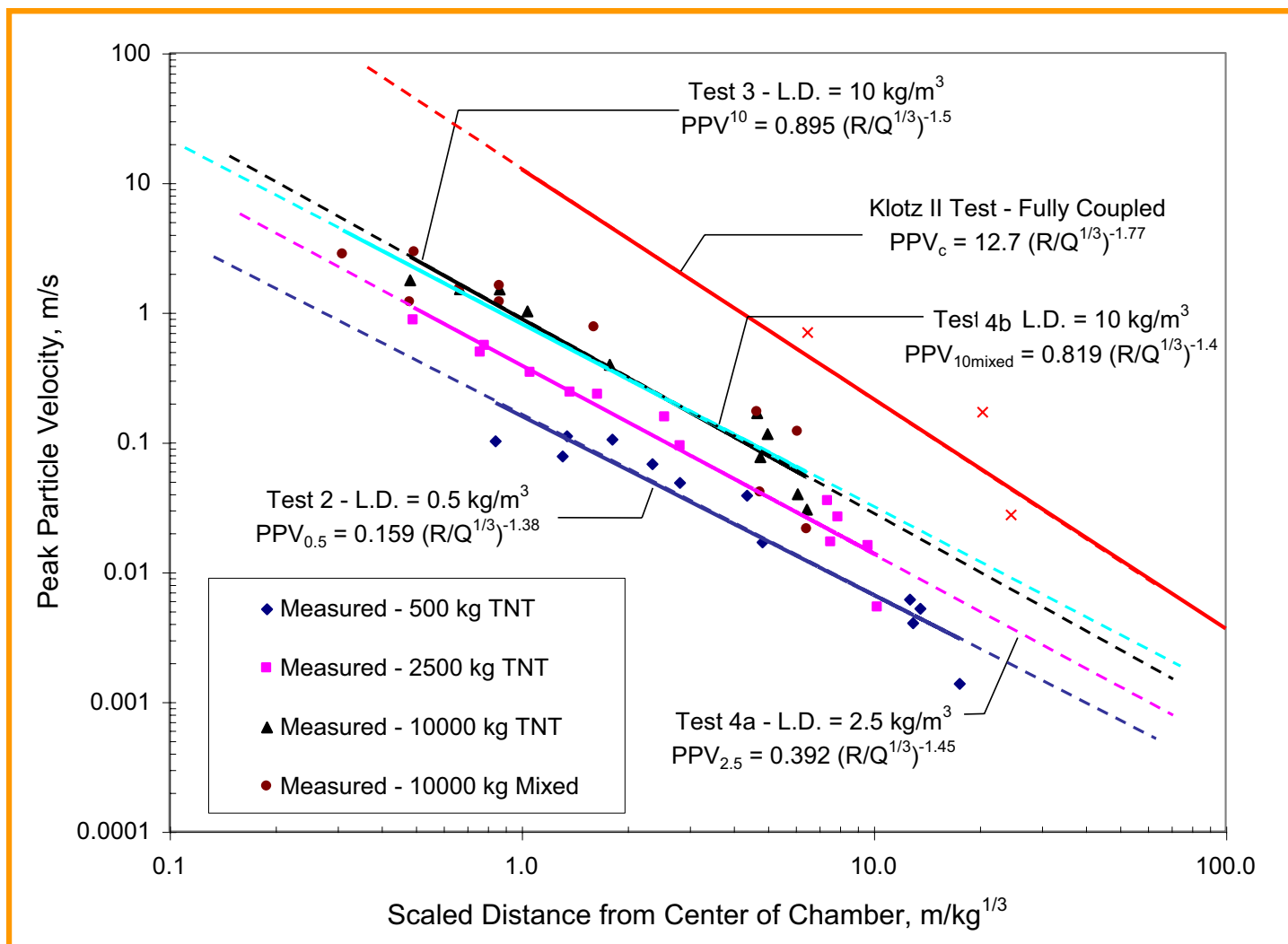


Figure 5. Comparison of peak particle velocities from coupled and de-coupled tests

5. Concluding remarks

Damage of unlined tunnels in competent rock does not seem to begin until the incipient PPV reaches a value of at least 1-2 m/s. With the addition of tunnel support (such as rockbolts and fibre reinforced shotcrete), it is expected that the tunnel can sustain a much higher load, probably at least 2-4 m/s in PPV. For such load cases, normal static rock support is probably sufficient, although the use of steel fibre reinforced shotcrete is recommended for its high energy capacity. The use of dynamic support is not necessary unless the dynamic loading, as expressed by the incipient peak particle velocity, reaches more than 2-4 m/s.

In predicting tunnel damage, accurate prediction of the ground shock loading is very important. The prediction must consider the type of load source and influencing factors such as charge

shape and loading density, as well as the rock mass properties. The effects of explosion loading on tunnels are very much a function of the loading density. For the same distance and same quantity of explosives, the peak particle velocity produced by a decoupled explosion of 10 kg/m³ is less than 10% of that of a fully coupled explosion.

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Spalling and the 2008 Wenchuan earthquake

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1. Introduction

In a recent field investigation of the May 2008 Wenchuan earthquake sites, we found clear evidence that some of the severe damage to villages was caused by the extremely large vertical ground acceleration. The same evidence was also found in the June 2008 Iwate-Miyagi earthquake¹ in Japan, in which an unprecedented vertical surface acceleration of nearly four times gravity was recorded, more than twice the horizontal acceleration. This is in marked contrast to the conventional models of earthquake ground motion, which focus usually on the horizontal ground motion.

Recently, Aoi *et al.* proposed a Trampoline Effect model¹ based on a mass bouncing on a trampoline to account for this large vertical amplitude. However, this model ignores the role of the stress wave effect and fails to predict the shallow surface fracture. Experimental and theoretical studies of rock dynamic failure show that, when a compressive wave hits the free surface, it will be reflected as a tensile wave and the acceleration or displacement doubles at the free boundary^{2,3}. Rock may then be fractured parallel to the reflecting surface if the tensile stress generated by the reflected wave reaches the tensile strength of the rock, and the fragments then shoot out from

the surface with considerable velocity, a phenomenon known as spalling.

It is possible to investigate the complete process of spalling with numerical analysis, from which one can derive an intuitive physical model to explain the presently unknown mode of strong ground motion with large vertical amplitude, and to explain the observed unusual phenomena of 'ground overturn' in the Wenchuan earthquake. Such a model should provide a better understanding of the near-source earthquake hazards.

2. The Wenchuan earthquake

On 12 May 2008, the devastating magnitude 8.0 Wenchuan earthquake struck the eastern edge of the Tibetan plateau⁴, collapsing buildings and killing thousands in major towns aligned along the western Sichuan basin. The powerful energy of the earthquake spread from Yingxiu Town in Wenchuan County, through Beichuan County to Qingchuan County (Figure 1). Many compressive and thrust belts, as well as many nappe structures broke out along the Longmenshan fault zone. The most typical site was Donghekou at Qingchuan, located at the end of the 300 km long Longmenshan fault (Figure 2).

Huge energy releases in the form of earthquake stress waves were transmitted from the focus to Qingchuan, where several sub-level faults intersected at Donghekou, resulting in wave superposition at the interface of the discontinuities. Large quantities of earth materials were pushed up by this huge tensile stress wave to the surface and some were vertically thrown out, a phenomenon often observed in subsurface explosions⁵, also called 'ground overturn', and reported by the local survivors from the earthquake. The damage, equivalent to a sub-surface nuclear bomb explosion, caused the four villages at Donghekou to disappear rapidly, and a 30-50 m earth mound, buried the houses and nearly 800 lives (Figure 2C).



Figure 1. On 12 May 2008, the devastating magnitude 8.0 Wenchuan earthquake struck the eastern edge of the Tibetan plateau in China.

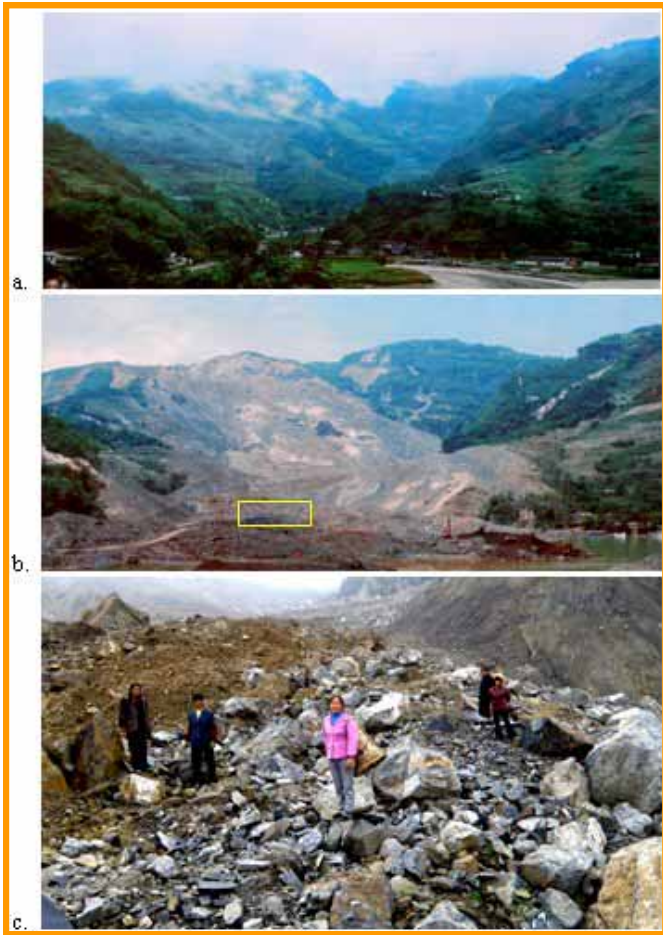


Figure 2. The Donghekou village
(a) before and
(b) after the 2008 Wenchuan earthquake.
The earthquake formed 30-50 m high
gravelly hills with hundreds of houses
destroyed and nearly 800 villagers
buried by the overturned ground.
(c) shows the rectangular portion in (b).



Figure 3 . The Xiejiadian village near
Longmen mountain of Pengzhou County
disappeared burying 16 houses
and costing more than 60 lives.

Evidence of ‘ground overturn’ due to extremely large vertical accelerations also exists in Xiejiadian, Longmen Mountain at Pengzhou, where a village with 16 houses was found to be completely disappeared during the Wenchuan earthquake (Figure 3).

3. Analysis

The above mentioned evidence from the Wenchuan earthquake strongly supports the finding of Aoi *et al.* regarding the unusually high vertical-to-horizontal peak acceleration ratio at the surface in an extreme ground motion¹. During the 14 June 2008 Iwate-Miyagi earthquake in Japan, one of the nationwide networks of strong motion seismographs recorded ground acceleration exceeding four times gravity, the largest ever reported to date, with the peak acceleration in the vertical direction being more than twice the horizontal. By contrast, they found that the 260 m depth down-hole records of vertical acceleration were much smaller than the one recorded at the surface level. This means that the unusual large accelerations on the surface should be attributed to the effects of the near-surface layers.

Based on stress wave theory^{2, 3, 6, 7}, it is well understood that, as an incident wave reaches a boundary, the solution is obtained by superimposing the incident and reflected waves. If the stress wave travelling in a solid strikes a free boundary perpendicularly, there will be a totally reflected wave at the boundary. The acceleration or displacement caused by the reflected wave is identical in form to the incident wave and is of the same sign. Superposition of the incident and the reflected waves leads to doubling of the outward acceleration or displacement at the free boundary.

So when an earthquake compressive wave hits the free ground surface, it will be reflected as a tensile wave, capable of breaking the rock mass by tension if the tensile stress generated by the reflected wave reaches the tensile strength of the rocks. The phenomenon is termed spalling in rock mechanics or solid mechanics⁸⁻¹².

When the reflected wave generates a tensile stress more than twice the tensile fracture strength of the rock, several parallel layers of rock may be broken and multiple spalling can occur. For example, the P-wave generated from the detonating

charge will hit the free surface as a compressive wave and will be reflected as a tensile wave, which may result in spalling and fragmentation of the rock².

The dynamics of spalling of the near-surface earth layers caused by contained underground explosions was investigated theoretically by Chilton *et al.*⁸ Some empirical studies of spalling have been made by Rinehart, Swift *et al.*, and Perret⁸.

Using a 1D bar model (Figure 4) and a 2D layered material model undergoing an impact, we have investigated the spalling process as a function of time based on finite element analysis. The heterogeneity of the rock is taken into account by assigning different properties to the individual elements according to a statistical distribution function. Random numbers satisfying Weibull's distribution were generated to give the spatial distribution of the microscopic strengths and elastic moduli. Element micro-scale properties are assigned to achieve the overall mechanical behaviour of the rock model to be elastic-brittle with residual strength. The macro-scale heterogeneity is also considered in a 2D model by distributing hard particles in the surface layer.

Elements are considered to fail when the stress in those elements reaches a certain failure criterion (threshold). The Mohr-Coulomb criterion with a tensile cut-off¹³ is used so that the elements may fail either in shear or in tension. The discontinuity feature of the initiated fracture of the rock is automatically included by using an element with very small stiffness when the tensile strain of the failed elements reaches certain values. A standard 2-D dynamic finite element code, called RFPA2D (realistic failure process analysis)¹⁴⁻¹⁸ is used to model the problem.

Figure 4 shows the numerically observed spalling of the bar. At the left end, a high velocity impact is applied. The compressive pulse initiates in the left side of the bar and propagates from left to right (stage a to c in Figure 4). Then, it is reflected from the free end on the right as a tensile stress wave (Figure 4c). When the tensile stress reaches the tensile strength of the material, spalling occurs, and part of the bar at the right end breaks off (Figure 4d). A new free end is formed and the remaining original incident wave is reflected from this new free end. Again, the bar



Figure 4. Numerical modelling of spalling in a one dimensional bar

end breaks when the reflected tensile stress wave reaches the tensile strength of the material, and a new free end is formed again. This process may continue and hence multiple spalling is generated (Figure 4, e-f). The results shown by the 1-D modelling are similar in 2-D modelling.

4. Conclusions

Our results provide a positive answer to the question addressed by O'Connell¹⁹ that it is not clear that the anomalous large vertical accelerations observed by Aoi *et al.*, could occur in the foundation of a structure at a site that has been compacted and had a foundation emplaced. Since the surface effect is caused by the seismic wave incident and reflection, the strong motion at the foundation level of buildings is inevitable if the magnitude of the earthquake is large enough and the epicentre is not far away from it.

We also believe that the same mechanism is applicable to explain the hundreds of slope surface failures in terms of spalling during the Wenchuan earthquake. Investigation at the Wenchuan earthquake site indicates that mountain slopes under dynamic shock waves fail in a manner completely different from slope failure under static gravity load. We found that most of the damaging earthquake-induced landslides only involve shallow rock falls and slides, which is believed to be caused by the stress wave incidence and reflection (Figure 5).

The same phenomena were also observed in the 2005 northern Pakistan earthquake (magnitude 7.6)²⁰, in which about 79% or 1,925 of the land-



Figure 5. Investigation at the Wenchuan earthquake site indicates that the mountain slopes under dynamic shock waves fail in a manner completely different from slopes that fail under static gravity load

slides were small and most of the small landslides are shallow rock falls and slides. To completely understand this, more numerical simulations should be conducted considering the real geometry of the slopes of the mountains with the real dynamic loads. These simulations should then provide new insights into understanding near-source earthquake hazards, which will be useful in focusing mitigation efforts and helping to select new sites for village or town rebuilding.

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You are invited to the 2010 ISRM Field Trip in Switzerland

**John A Hudson, UK (john.a.hudson@gmail.com) &
Luis Lamas, Portugal, (secretariat.isrm@lnec.pt)**



Christophe Bonnard
Field Trip Leader

Sunday and Monday, 13 & 14 June 2010

This 2nd ISRM Annual Field Trip takes place in June 2010 on the two days immediately before the EUROCK2010 Symposium.

It starts and finishes in Lausanne, Switzerland.



12th century Chillon castle, on the Lake Geneva shore, displays furniture and medieval weapons

The anticipated outline schedule of the Field Trip visits is given below

Sunday 13 June 2010

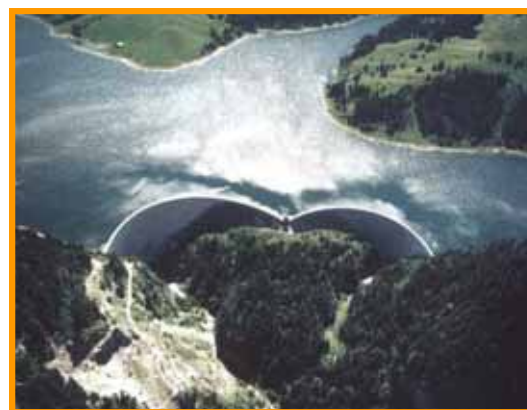
- 08.00 Meeting of the group in front of Lausanne cathedral (XIIIth century, visit to the painted porch)
- 08.30 Travel by bus to Belmont and see high rebuilt anchored wall along Motorway A9
- 09.30 Travel by bus to Chexbres stopping at the Cornallaz landslide and seeing mollasse outcrop
- 10.30 Travel by bus to Fribourg with stop for coffee at La Gruyère service area on the A12
- 11.30 Visit to Fribourg old town located along the Mollasse cliffs formed by the river Sarine
- 12.30 Lunch in a restaurant in Fribourg
- 14.00 Travel by bus to Falli Hölli landslide near Plasselb, with a look at the Zollhaus outcrop
- 16.00 Travel by bus to Gruyères, with visit to the ancient castle and village; typical dinner in a restaurant and overnight in a nice hotel (La Fleur de Lys)



1994 Falli Hölli landslide with a displacement of 250 m in 4 months

Monday 14 June 2010

- 08.00 Travel to l'Etivaz cheese cave, stopping on the way to see some outcrops of the Prealps formations
- 10.00 Travel to the double arch Hongrin dam and visit to the Aigremont rockfall zone
- 12.00 Lunch in a restaurant at Le Sépey (maybe picnic)
- 14.00 Visit La Frasse landslide and recently built drainage gallery
- 17.00 Look at a Dolomite quarry at Villeneuve (large rockfall in 1922) that is still exploited
- 18.00 Visit to Chillon castle between Villeneuve and Lausanne
- 19.30 Arrival back in Lausanne



Hongrin dam

Field Trip cost will be ~ €250
To register:
contact Sofia Meess at
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The Field Trip information will be updated on the ISRM website: www.isrm.net

You are invited to EUROCK2010 in Switzerland: 15-18 June

Jian Zhao, Switzerland (jian.zhao@epfl.ch)



EUROCK2010

EUROCK2010 is organised by the Swiss National Group of ISRM and the Swiss Federal Institute of Technology in Lausanne (EPFL), and the Organising Committee is chaired by Jian Zhao. The symposium will take place on the EPFL campus on Lake Geneva on 15-18 June 2010.

ABSTRACTS RECEIVED

EUROCK2010 has received an overwhelming number of abstracts – exceeding 340. Consider-

ing all the limitations, we accepted 220 abstracts from 36 countries and the authors are preparing full-length papers and presentations.

KEYNOTES AND SPECIAL PRESENTATIONS

- Keynotes will be given by Herbert Einstein, Claus Erichsen, Peter Kaiser, Marek Kwaśniewski, Jean Sulem, and Robert Zimmerman.
- Special presentations will be given on the DECOVALEX and TIMODAZ radioactive waste repository modelling projects and on the construction of the Lötschberg and the Gotthard long base tunnels.
- At the Open Session there will be overview reports on rock mechanics teaching, research, engineering activities in Europe and the future outlook. The Open Session will be chaired by Giovanni Barla and Håkan Stille.



OTHER EVENTS

A pre-Symposium field trip, the 2nd Annual ISRM Field Trip, has been organized by the ISRM – and details of the trip are available on the opposite page. We have also planned a few options for technical visits on 18 June, the last day of the Symposium, primarily to the tunnelling and slope sites. Short courses will be organised; several proposals have been received; these will be evaluated and announced on the Symposium website.



EXHIBITION AND SPONSORSHIP

In conjunction with the Symposium, we will have Exhibitions by consultants, contractors and suppliers, as well as a set of 48 panels (each 2m x 1m) entitled “New Rail Link through the Alps: a Swiss Pioneer Achievement” by the Foundation “Hänggiburm” Ennenda and Museum for the Art of Civil Engineering.

Companies wishing to have an Exhibition stand at the Symposium and/or wishing to sponsor the Symposium, please email the Symposium organiser directly for detailed



Further information is available at the Symposium website: <http://lmr.epfl.ch/eurock2010>

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