



# NEWS JOURNAL



ISRM

International Society for Rock Mechanics and Rock Engineering



## ANNUAL REVIEW 2022

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- SECRETARY-GENERAL'S REPORT
- AWARDS
- CONFERENCE REPORTS

## SURVEY RESPONSES

## TECHNICAL PAPERS

- FRANKLIN LECTURE
- ROCHA MEDAL LECTURE
- JOHN HUDSON ROCK ENGINEERING AWARD

## ISRM COMING EVENTS

## 15th ISRM International Congress

Challenges in Rock Mechanics and Rock Engineering

9-15 October 2023  
Salzburg, Austria



## 15th ISRM INTERNATIONAL CONGRESS AND 72nd GEOMECHANICS COLLOQUIUM 2023

OCTOBER 9th TO 15th 2023



The Austrian Society for Geomechanics has the pleasure to invite you to the 15th ISRM International Congress 2023 to be held in conjunction with the 72nd Geomechanics Colloquium in Salzburg, the city where the International Society for Rock Mechanics (ISRM) was founded in 1962.

The Geomechanics Colloquium in Salzburg since its initiation in 1951 has always been a perfect and distinguished meeting place for researchers and practitioners. The success of this concept not only shows in the continuous meetings over more than 70 years, but also in the attendance of regularly around 1000 participants.

We have put some effort in preparing an interesting and attractive scientific program. Interesting site visits to tunnel and rock engineering projects will be organized. The Congress will be preceded by interesting short courses, workshops and seminars.

Salzburg is famous for its unique historical city center, and the wonderful Alpine landscape in the vicinity, as well as for outstanding music festivals. Mozart was born in Salzburg and spent a good deal of his life here. Traditionally a chamber concert is organized for the participants. The accompanying persons' program will include city tours, and tours to scenic and interesting places in the vicinity of the city.

### Themes include:

- Deep geothermal energy
- Underground storage for liquid and gaseous media
- Geological risks and natural hazards
- Long term behaviour of underground structures
- Challenging rock engineering projects
- Digitalization & Automatisaton
- Monitoring
- Numerical methods in rock engineering
- Geological investigation and characterization
- New developments in rock support
- NATM versus TBM
- Comparison of international tunnelling contracts
- Hydropower projects and dams
- Rock and rock mass properties
- Deep mining and tunnelling
- Petroleum engineering and carbon sequestration
- Rock slope engineering

### Preliminary planned workshops, seminars, short courses:

- Planetary rock mechanics
- Rock slopes stability analyses - from photogrammetric 3D models to stability assessment
- Eurocode 7
- Up to date sealing and grouting systems in civil and underground engineering; systems, function, sustainability, practical examples
- Numerical Modeling Assisted Risk Quantification in Rock Masses
- The rock engineering challenge

### Important dates:

Full paper submission deadline	January 31st 2023
Final paper submission deadline	May 31st 2023
Early bird registration deadline	June 30th 2023

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Internationella bergmekanikföreningen

# NEWS JOURNAL

ISRM

International Society for Rock Mechanics and Rock Engineering

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## LETTER FROM THE EDITORS

Though it seems a lifetime, it was just a couple of years ago that the COVID-19 pandemic struck as preparations for scientific events were well underway and organizers had to adapt and do everything they could and switch to new complete virtual events. In the past years, some ISRM sponsored conferences and scientific events were cancelled or postponed, but at the end many were successfully staged online. A number of aspects relating with virtual conferences exceeded expectations: speakers rehearsed better and stuck to time, while moderators were able to select the most relevant questions, talks ran smoothly, discussion sessions enabled broader participation, and audience numbers, especially for young members, were encouraging. However, despite these accomplishments, some crucial features were missing, as the pleasures of meeting old friends and making new acquaintances, the gatherings in the halls, the interaction with the exhibitors, the fruitful face-to-face discussions and exchange of know-how.

So it is not surprising that lots of people wanted to get back to together and attend in-person meetings. After two successive years, the ISRM Council meeting was held face-to-face again before the International Symposium in Asunción, Paraguay. To mark this occasion the cover photo of this year's News Journal issue shows the participants in the Council meeting; it makes a meaningful difference with the mosaic images on the previous issues, which tried to portray the virtual activities that were carried out in the past two years.

In 2022 ISRM activities returned to regular operation. The ISRM Council meeting was once more held face-to-face in Asunción, Paraguay. It followed previous online Council meetings in 2020 and 2021, and the last face-to-face meeting in 2019 on occasion of the 14th ISRM International Congress in Foz do Iguaçu, Brazil. Seven other ISRM regional, specialized or sponsored meetings were also held all over the world, from Africa (TuniRock2022) to Australasia (AusRock2022), going through Europe (5th Macedonian Symposium and Eurock2022), Asia (RocDyn4 and ARMS12), Latin-America (Cobramseg 2022) and North-America (CouFrac2022).

In the past years, ISRM took advantage of virtual lectures and training courses, as they can reach larger and new audiences, or they can be downloaded and watched at leisure. In addition to the usual four Online Lectures, in 2022 two more video courses and the presentations delivered at the Workshop of the Commission on Testing Methods, held during Eurock 2022, in Helsinki, were added to the ISRM website.

"Going virtual" is something that attracted the participation of younger members, which are essential to the renewal of the ISRM. Following the International Webinars on Rock Mechanics, the ISRM Young Members' Seminar Series was established in November 2021 to provide a platform for young members to collaborate and showcase their achievements. In 2022, the organizing committee delivered 11 live seminars with 22 speakers from all over the world. The recordings of these presentations are available on the ISRM Young Members YouTube channel.

The 2022 Members Survey revealed some contrasting facts: on one hand, our society is aging and the rate of attracting new members is too low (only 13% of the respondents were with less than five years into rock mechanics and rock engineering profession, whilst 23% of respondents had over 30 years of experience), and on the other, respondents rated ISRM good to very good in achieving its goals, and they were also positive with the ISRM engaging in promoting the profession amongst public and next generations, and activities related to sensitive environmental topics. Respondents also forwarded their views regarding the future of the ISRM, namely concerning the easier, inexpensive access to materials and conferences, or new innovative topics, which will certainly be responded by the Board.

This year demonstrated that people were eager to meet again, re-establish human contacts and return to in-person activities, but recent surveys suggest that a majority of researchers in various scientific domains would like to see virtual conferences, online courses and remain after the effects of the pandemic vanish. These past years taught us that there are pluses and minuses in face-to-face and virtual activities. It is up to us to take the best out of both of them. 🌟

Reşat Ulusay and José Muralha  
News Journal Editors



## ISRM Specialized Conference

## IV NROCK2023

24-26 May 2023  
Reykjavik, Iceland

## THE IV NORDIC SYMPOSIUM ON ROCK MECHANICS AND ROCK ENGINEERING

REYKJAVIK ICELAND

24 - 26 MAY 2023



The Icelandic Geotechnical Society and the Icelandic Tunnelling Society are Organizing the IV Nordic Symposium on Rock Mechanics and Rock Engineering in Reykjavik, Iceland, 24 - 26 of May 2023.

This symposium gathers Nordic rock mechanics and engineering geology experts to discuss the current state of research, infrastructure, rock caverns, tunnelling, mining, use of underground space for energy recovery and storage, and case histories. Use of underground space for various purposes is a natural choice in Nordic countries and it has made the understanding of rock mechanics and rock engineering vital.

[www.nrock2023.com](http://www.nrock2023.com)

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### BERGMEKANIKK I NORDEN

The Nordic Rock Meeting was established by the Norwegian Rock Mechanic Group and the first meeting was held in Norway in 2010, followed by meetings in Sweden and Finland. The next meeting, the 4th, is planned in Reykjavik, Iceland in 2023.

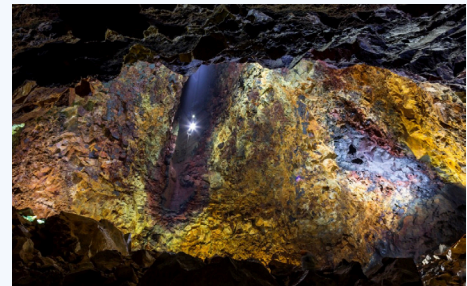
#### The Nordic Rock Meetings

2010 Kongsberg - Norway

2013 Göteborg - Sweden

2017 Helsinki - Finland

2023 Reykjavik - Iceland



The aim of the symposium is to strengthen the relationships between practicing engineers, researchers and scientists within the fields of Rock Mechanics and Engineering Geology with special emphasis on, but not limited to, the Nordic region.

All are invited to share their experience and knowledge with their Nordic colleagues by participating in the technical program as well as in the social one.

## ISRM Sponsored Conference

## 3rd JTC1 Workshop

7-10 June 2023  
Oslo, Norway



The Joint Technical Committee on Natural Slopes and Landslides (JTC1) of FedIGS is inviting all to join at the 3rd JTC1 Workshop on Impact of global changes on landslide hazard and risk, to be held in Oslo, Norway, on June 7th - 10th, 2023.

Anthropogenically induced climate change is unquestionably changing landslide hazard and risk, and impacting how we assess and manage them.

The aim of the Workshop is to promote discussion among scientists, engineers, decisionmakers and other stakeholders on whether we are capable of predicting and quantifying the expected changes in landslide hazard and risk and how we could implement the knowledge gained from academic research on landslide risk management into practice. The advanced topics in focus for the discussions include:

Rock mass degradation and landslide initiation

Climate and anthropogenic impact on landslide risk in various geographic regions, including the Arctic

Prediction of landslide mobility and inundation, including landslides initiated at mine tailings storage facilities

Application of modern remote sensing technologies to landslide risk assessment

Landslide risk reduction strategies: risk mitigation, including early warning and nature-based solutions

Applications of new technologies like machine learning for landslide susceptibility and landslide hazard mapping

<https://jtc1-2023.com>

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## ISRM Specialized Conference

10th Nordic Grouting Symposium

11-13 September 2023  
Stockholm, Sweden**NGS 2023**

10th Nordic Grouting Symposium



The Swedish Rock Engineering Association is organizing the 10th Nordic Grouting Symposium, which will be held at the Stockholm City Conference Center. The symposium gathers experts to exchange experiences and discuss the latest developments and achievements in the field of rock grouting. It continues the tradition of the Nordic Grouting Symposia that started in Gothenburg, Sweden in 1992.

The symposium themes include a range of topics, as well as a workshop as part of the program. Environmental aspects, grouting cases, novel methods for grouting execution and hydraulic tests are just a few of the topics this symposium aims to present.

<https://www.ngs2023.se>
[info@svbergsteknik.se](mailto:info@svbergsteknik.se)

## ISRM Specialized Conference

1st Chilean Congress on Rock Mechanics

22-24 November 2023  
Santiago, Chile

The 1st Chilean Rock Mechanics Congress, organized by the Chilean Rock Mechanics Society and the Mining Engineering Department of the University of Santiago, seeks to create a space where both industry and universities can present experiences and research in different areas of rock mechanics, promoting the formation of ties and networks between experts, suppliers, students, and stakeholders.

This congress will be held between November 22 and 24, 2023, at the Marina las Condes Hotel, Santiago, where, in addition to technical presentations, different events will be prepared to share with all those who are passionate about rock mechanics.

[www.congresomecanicarocas.cl/](http://www.congresomecanicarocas.cl/)
[alejandravillouta@gmail.com](mailto:alejandravillouta@gmail.com)

## ISRM Specialized Conference

1st SLRME Conference

2-7 December 2023  
Colombo, Sri Lanka

The Sri Lankan Rock Mechanics and Engineering Society (SLRMES) invites you to participate in the 1st SLRMES Conference on Rock Mechanics for Infrastructure and Geo-Resources Development to be held in Colombo, Sri Lanka, during December 2-7, 2023. The first two days are allocated for the short courses and workshops. The plenary and technical lectures of the conference are planned for the next two days, and the last two days are allocated for the technical and sightseeing tours.

The conference will cover advances in all areas of rock mechanics and rock engineering encompassing the fields of mining, civil, geological, and petroleum engineering, and geophysics and Hydrogeology focusing on the theme "Rock Mechanics for Infrastructure and Geo-Resources Development". Three keynotes are expected to be delivered to cover the state-of-the-art on several important topics. Each session is expected to start with a Session Lead Lecture given by an expert on the session topic. The plenary and technical lectures, short courses, workshops, technical tours, and trade exhibition programs are organized to provide conference supporters maximum exposure and interaction with participants from universities, industry, government, and exhibitors. Visits are also planned to tourist attractions in Sri Lanka.

<http://www.slrme.org>
[kulatil@u.arizona.edu](mailto:kulatil@u.arizona.edu)

## ISRM Regional Symposium

Eurock 2024

15-19 July 2024  
Alicante, Spain



Universitat d'Alacant  
Universidad de Alicante



The Alicante University and the Spanish Society for Rock Mechanics (SEMR) are organizing the Eurock 2024, the ISRM European Regional Symposium, to be held in Alicante, Spain, during July 15-19, 2024.

The conference title is New challenges in rock mechanics and rock engineering, and the following topics will be addressed:

- Rock properties, testing methods and site characterization
- Rock mechanics for infrastructures
- Mining rock mechanics and rock engineering
- Design methods and analysis
- Rock mechanics for heritage
- Geophysics in rock mechanics
- Numerical modelling and back analysis
- Monitoring and back analysis
- Underground excavation and support
- Risk and hazard
- Applicability of EUROCODE-7 in rock engineering
- Geomechanics for the oil and gas industry
- Ores, building and industrial rocks
- Application of artificial intelligence to problems of rock mechanics
- Remote sensing in rock mechanics
- Geothermal technology
- Rock Mechanics education and training

[www.eurock2024.com](http://www.eurock2024.com)

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## ISRM International Symposium

ARMS13

24-28 September 2024  
New Dehli, India



The ISRM Asian Regional Symposium will be organized by the ISRM NG from India, in New Dehli, from 24 to 28 September. It will host the ISRM Council meeting, since it is also the ISRM International Symposium.

The conference title is Advances in Rock Mechanics - Infrastructure Development, and the following themes will be addressed:

- Advancement in Site Investigations and Characterisation of Rocks & Rock Masses
- Application of Advance Geophysical Investigation Techniques
- Constitutive Modelling of Rocks and Soils
- Rock and Dump Slope Stability and Foundation Analysis
- Rock Supports, Instrumentations and Ground Improvement
- Design Methods and Analysis – Analytical and Numerical Modelling
- Preservation and Restoration of Ancient Monuments
- Deep Underground Mining Methods and Instrumentation
- Underground Space Development for Storages and other purposes
- Innovations and Applications of IoT in Rock Engineering
- Structural Health Monitoring and Rehabilitation
- Advancement in Laboratory Testing Techniques.
- Geo-hazards and Risk Management
- Green Technologies for Zero Waste Generation and Sustainable Development
- Case Studies

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## 02 PRESIDENT'S ADDRESS



Dear Colleagues,

A new year has begun and it is a great pleasure for me to address all of you again to summarize our activities during 2022. Although 2020 and 2021 were marked by Covid19 lockdowns and travel restrictions and we had to comply with the new living circumstances and adjust ISRM activities to the new situation, 2022 was a chance to start the normalization of the ISRM activities as they were before 2020 to continue our performance, enhance ISRM services and to grow. This year all ISRM conferences, workshops, Board and Council meetings were successfully organized as face-to-face events and we had the opportunity to see each other again in these events after two years. In 2022, ISRM also continued to pay attention to the use of web-based tools, such as video conferences, webinars, and online conferences. In this message, I would like to make a brief retrospective of the ISRM activities during 2022.

### ISRM Meetings

All ISRM meetings in 2022 were held as scheduled. One on-line interim meeting and the physical annual meeting of the Board were held in May and October, respectively. The 2022 ISRM Council meeting was also held in October as a face-to-face meeting just before the ISRM International Symposium (LARMS 2022) in Asunción, Paraguay, with the participation of the representatives of 45 National Groups, one ISRM Past President (Dr. Eda Quadros) and several past ISRM Vice Presidents. In addition, the 2022 European and Asian Council meetings were also successfully held as face-to-face meetings in October during LARMS2022 and ARMS12 in Hanoi (Vietnam), respectively.

### ISRM Commissions

Fifteen ISRM Commissions submitted their annual reports to the ISRM Technical Oversight Committee (TOC). An extensive report describing the activities of the ISRM Commissions in 2022 was prepared by the TOC, which is presented in this issue with details and comments of the objectives and products of the Commissions. The 2022 annual meetings of the ISRM Commissions were mostly held online. The majority of the Commissions have held workshops or organized sessions at major conferences on their topic of interest and a book written by the Commission on Underground Nuclear Power Plants will be published soon. Eleven new ISRM Suggested Methods are in preparation and the Commission of Testing Methods will also publish a book when around 15 new Suggested Methods are published. Based on the TOC report, I am very glad to inform our society that the majority of the ISRM Commissions are performing at a high level or at a sufficient level with no major concerns. I sincerely thank our Commissions and TOC members.

### ISRM Sponsored Conferences

On the contrary to those held in the last two years, in 2022 eight face-to-face and one hybrid ISRM Sponsored Conferences were successfully organized with the close cooperation of ISRM National Groups. These events were TuniRock2022 (Tunisia), 5th MAG Symposium (Macedonia), RocDyn4 (China), Cobramseg 2022 (Brazil), EUROCK2022 (Finland), LARMS2022 (ISRM International Symposium, Paraguay), CouFrac2022 (USA), ARMS12 (Vietnam) and AusRock2022 (Australia). I attended four of these events. Although the pandemic conditions have not yet fully passed in the world, I am very glad with the increase in the number of face-to-face successful ISRM sponsored conferences. I congratulate the organizing committees of all these events and all participants.

### ISRM Awards

Among four nominations Prof. Derek Martin from Canada was selected by the ISRM Council, at its meeting in Asunción, Paraguay, to receive the 9th Müller Award. He will deliver the Müller Lecture during the 15th ISRM

International Congress in Salzburg, Austria, in 2023. The Board analyzed 23 candidate theses and Radhika de Silva from Sri Lanka (Monash University, Australia) was selected as the winner of the Rocha Medal 2022 and delivered the Rocha Lecture in LARMS2022. Two runner-up certificates were also given to Masoud Rahjoo, from Iran, (Univ. of British Colombia, Canada) and Xiaofeng Li from China (Inst. Rock Soil Mechanics). The 2022 Science Achievement Award and Young Rock Engineer Award were given to Prof. Jean Sulem (France) and Dr Yota Togashi (Japan), respectively. Dr Christine Detournay from the USA was selected for the John Hudson Rock Engineering Award 2022, and Dr Werner Bilfinger from Brazil was selected for the 2022 Franklin Lecture and delivered his lecture in LARMS2022. I congratulate all winners and wish continuation of their successes.

#### ISRM Online Lectures

In 2022, the ISRM organized four ISRM Online Lectures, which were delivered by Prof. Yuzo Ohnishi (Japan), Dr Yingxin Zhou (China), Emeritus Prof. Bruce Hebblewhite (Australia), and Dr José Delgado Rodrigues (Portugal). I sincerely thank all lecturers for their time to prepare lectures and for their very kind contribution to the ISRM. Currently, a total of 40 Online Lectures are available in the ISRM website.

#### ISRM Book Series

We are doing our best for the publication of new books in the ISRM Book Series. I am glad that a new book, written by the ISRM Commission on Underground Nuclear Power Plants, chaired by Prof. Shunsuke Sakurai, was submitted to the publisher and will be published soon. Another book written by Prof. Ömer Aydan entitled "Abandoned Room and Pillar Mines and Remediation Measures" will also be published in 2023. A third book entitled "Flow of Water in Fractured Rock Masses: Basic Theory & Practical Applications" is in preparation by Dr Eda Quadros and Dr Philippe Vaskou. As the Co-editors of the ISRM Book Series, Prof. Xia-Ting Feng and I kindly invite our Commissions and colleagues to send their reports and books, respectively, to be published in the ISRM Book Series.

#### Video Courses

This year two new video courses on "Rockburst in deep tunnels" (Prof. Xia-Ting Feng) and "Crustal Stress Assessment and its Application in Engineering and Earthquake Research" (Profs. Furen Xie and Jiayong Tian) were added to the list of ISRM videos. We thank the hard work of the experts who prepared these courses. In addition, we expect that two new video courses will be available on our website in 2023.

#### ISRM Survey

Only once in 2008 a survey to ISRM members was done. The new ISRM survey was sent to National Groups for distribution to all their ISRM members and non-members between March and April 2022. The responses from 737 respondents were analyzed and

the results and conclusions are given in the Survey Report that is also available in this journal. Many of the results from the Survey were very useful for guiding the direction for the Society. I thank the ISRM Young Members Committee for their kind efforts for the preparation and evaluation of this most recent survey and to all respondents for their very kind interests and contributions.

#### ISRM Memberships

ISRM reached almost 9000 individual members. Although our target in 2020 and 2021 was to bring new members, the pandemic affecting the entire world did not allow us to increase this number. With the last National Group that joined us in 2022, which was the National Group of Sri Lanka, our Society has now 59 National Groups. In addition, Bangladesh also prepares application documents for the membership to ISRM in 2023. I am glad to inform that our Vice Presidents are in contact with colleagues from other countries for the establishment of new National Groups and have been actively encouraging National Groups to organize events in their rock mechanics and rock engineering communities.

#### ISRM Early Career Forums

This program started its activity during the AfriRock 2017 Symposium in Cape Town, financially supported by the ISRM Education Fund and continued regularly ever since. This year the forum was successfully held in LARMS2022 in Asunción, Paraguay, and nine young speakers selected from eight ISRM Latin America countries delivered their presentations. In addition, in AusRock2022, other Early Career Forum was also organized by its Organizing Committee. I congratulate all young speakers in these forums and thank the organizers of both events and the ISRM Education Fund Committee.

#### New Initiatives

I am very glad to inform our society that the most recent ISRM initiative - the "ISRM Young Members Seminar Series", developed by the members of ISRM Young Members Committee - started on January 2022. It is a series of monthly virtual seminars, with the goal of providing a global platform for ISRM young members to share knowledge, experiences, and ideas. Until the end of 2022 these monthly seminars have been regularly and successfully organized. I kindly invite young colleagues, who wants to give a seminar, to contact the ISRM Young Members' Seminar Series Organizing Committee. ISRM European Rock Mechanics Debates, started in 2021, also successfully continued in 2022.

#### Cooperation with Sister Societies

The online FedIGS Board meeting was held on 21 September 2022 with the participation of its Board members representing ISSMGE, IAEG, IGS and ISRM. The meeting was chaired by its new President, Prof. Chungsik Yoo. In this meeting, ISRM was represented by me, our Immediate Past President Eda Quadros and our Secretary General Luis Lamas. Preparation

02 of a proposal for a new 'Joint Technical Committee on Environment and Geo-sustainability, and interaction between member societies (such as FedIGS Plenary Session / FedIGS Keynote/ FedIGS WhatsApp Group/ FedIGS Forum/ FedIGS Lectures) were accepted as new initiatives in this meeting.

#### Other Issues

Added to all the reported activities, the organization of the next ISRM International Congress on Rock Mechanics, which will be held in Salzburg, Austria, in October 2023, is going ahead with great energy, under the guidance of the Chairman and Co-chairmen of the Organizing Committee. I greatly thank their work and commitment as well as of all the members of the Organizing Committee. The decision concerning the venue of the 16th ISRM Congress to be held in 2027 was taken in the 2022 Council meeting and among the three excellent proposals the Korean proposal was selected. I congratulate the Korean NG and wish them successes. Unfortunately, in 2022, Prof. Álvaro González García (Colombia), who was the VP for South America between 2007-2011, and Emeritus Prof. Pierre Berest (France) passed away. We will never forget their

kindness and great contributions to Rock Mechanics and Rock Engineering and the ISRM, and we will keep their memories alive for the next generations.

Finally, I would like to sincerely thank the strong involvement of the ISRM Vice Presidents and ISRM Secretary-General, the Chairs and members of the ISRM Commissions and of the three ISRM Committees, our Past Presidents and Fellows, our Secretariat, the Webmaster and the Co-editor of the ISRM News Journal in Lisbon, and the contributions given by our National Groups and our individual members for the success of ISRM, as well as the National Laboratory for Civil Engineering (LNEC) in Lisbon for providing the ISRM Secretariat facilities since its foundation.

I wish all of you a Happy New Year 2023 with full of good health, success and peace, hoping to meeting you in the 15th ISRM Congress and other ISRM activities in next year. 🇳🇵

Reşat Ulusay  
ISRM President

## ISRM PRESIDENT VISITED THE VIETNAMESE NG

The ISRM President attended the 12th Asian Rock Mechanics Symposium (ARMS12) held in Hanoi, Vietnam, between 23 and 24 November, and, in the previous day, he visited the Vietnamese Society for Rock Mechanics (VSRM), the Vietnamese ISRM National Group.

Prof. Ulusay thanked the VSRM board members for the past ISRM events organized in Vietnam by VSRM and their kind efforts for the organization of ARMS12 as an ISRM in-person event after the undesirable circumstances caused by the Covid 19 pandemic. He also emphasized that the ISRM Board will be very glad with the participation of VSRM members in future ISRM symposia and congresses and other ISRM activities and commissions. The VSRM Board members mentioned that they desired to be more active in ISRM, and their members can contribute in the field of petroleum geomechanics, and that the organization of an ISRM Lecture Tour in Vietnam would be very useful. 🇳🇵

ISRM President and VSRM Board in front of the Institute Geological Sciences, of the Vietnam Academy of Science and Technology, in Hanoi.



From left to right: Dr Pham Quoc Tuan (Secretary-General), Prof. Do Nhu Trang (VSRM Vice), Prof. Resat Ulusay, Prof. Nguyen Sy Ngoc (VSRM President), and Assoc. Prof. Tran Thu Hang (Board Member of VSRM)



THE 2019-2023  
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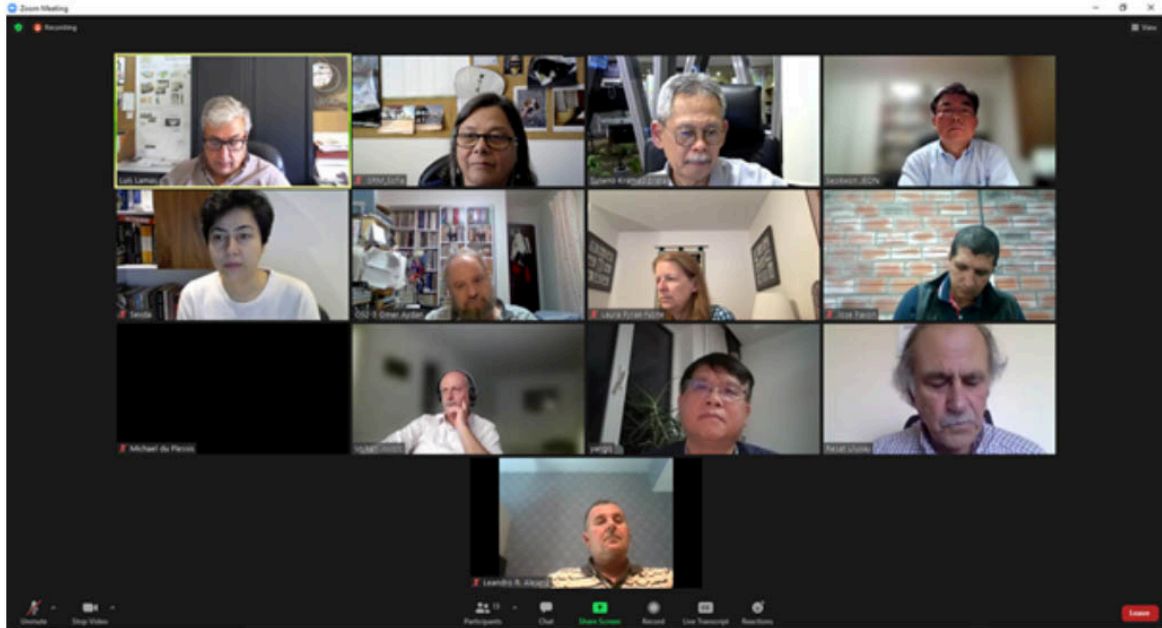
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## 04 ISRM BOARD ACTIVITIES

Following the experience gained in previous years with virtual events, the Board decided to hold an interim virtual meeting on 12 May, besides the in-person meeting held on 14 October during the IX LARMS symposium, in Asunción, Paraguay.



Interim Board Meeting on 12 May

The current, on-going affairs of the society were addressed in both meetings, all board members and committees chairs presented their recent activities and the organizers of the forthcoming ISRM conferences provided brief presentations of the status of the organization of the events. In these meetings, several relevant decisions were taken.

The Board, acting as Rocha Award Committee, screened the 19 candidate theses and selected Jun Zhao, from China, as the winner of the Rocha Medal 2023, with his thesis presented at the Northeastern University, China, and supervised by Xia-Ting Feng. The Board also decided to award two run up certificates to Rupesh Verma, from India, for a thesis presented at the University of Adelaide, Australia and supervised by Giang D. Nguyen, and to Cyrille Couture, from Canada, for a thesis presented at the Université Grenoble Alpes, France and supervised by Pierre Bésuelle.

Minor revisions were introduced to the Guideline for Allocation of Page Quotas to National Groups for ISRM Congress Proceedings updating the criterion for determination of contributions and the



Board meeting on 14 and 15 October in Asunción, Paraguay

number of pages allowed for the proceedings given the changes that digital proceedings have introduced, to the Guideline for the John Hudson Rock Engineering Award allowing more space for the descriptive report of the candidates, and to the Guideline on the Science and Technology Awards also allowing more space and requesting a video presentation during the award ceremony and the paper to be published in the ISRM News Journal.

Following the presentation of the application of the NG Norway for Eurock 2025 as an ISRM Regional Symposium, to take place in Trondheim, Norway, in June 2025, by Leandro Alejano on behalf of the Organizing Committee, the Board approved Eurock 2025 as an ISRM Regional Symposium.

The ISRM Council meeting, held on 16 October 2022 in Asunción, Paraguay, was attended by 45 National Groups, the Board members, the Past President Eda Quadros and observers from the National Groups.

The Council approved by acclamation the proposal of the National Group of India to host the 2024 ISRM International Symposium in New Delhi, since it was the only application received.



The 2022 ISRM Survey was released between March and April to ISRM members and non-members, and received 737 replies (84% members and 16% non-members).

The survey allowed to characterize the ISRM membership, namely in what regards demographics, member education and fields of work, experience and longevity. It enquired the reasons for joining ISRM and the member's engagements, and asked to rate the ISRM goals and achievements, services and offerings. The final open questions concern the future; they enquired about the top most important issues in Rock Mechanics and Rock Engineering still to be answered, the newest innovations and technologies, the changes that ISRM should implement, among others.

The answers of the respondents and respective analysis is presented in this issue of the News Journal.

The National Groups of China, New Zealand and Korea presented excellent proposals to host the 16th ISRM International Congress on Rock Mechanics in Beijing, Christchurch, and Seoul, respectively. After voting, the Council selected the Korean proposal, and thus the Congress will take place between 17 and 23 October 2027, in Seoul.

The Müller Award is the most prestigious distinction of the ISRM, awarded once every four years at the ISRM Congress, in recognition of distinguished contributions to the profession of rock mechanics and rock engineering. The Council appraised the four nominations received – Derek Martin from Canada, Manchao He from China, Marc Panet from France and Nielen van der Merwe from South Africa – and Prof. Derek Martin was selected to receive the award. He will deliver the Müller Lecture during the 15th ISRM International Congress in Salzburg, Austria, in October 2023.

Several awards were announced in the Council meeting:

The John Hudson Rock Engineering Award 2022 conferred on individual or corporate members of the ISRM in recognition of achievements in engineering practice given to Dr Christine Detournay, USA

The Science Achievement Award 2022 in recognition for outstanding contributions to science and technology in the field of rock mechanics and rock engineering conferred on Prof. Jean Sulem, nominated by the NG France

The Young Rock Engineer Award 2022 acknowledging excellence in the field of rock engineering by ISRM members who are in early stages of their career conferred on Dr Yota Togashi, nominated by the NG Japan 🇯🇵



## 05 REPORT OF THE ISRM SECRETARY-GENERAL 2022

### 1 - NATIONAL GROUPS AND MEMBERSHIP

The number of individual members (ordinary and corresponding) and of corporate members on the occasion of the Council meeting in October 2022 is presented in the following table. The National Group of Iran having been excluded on 31 December 2021, the current number of ISRM National Groups – also presented in the table – is 58.

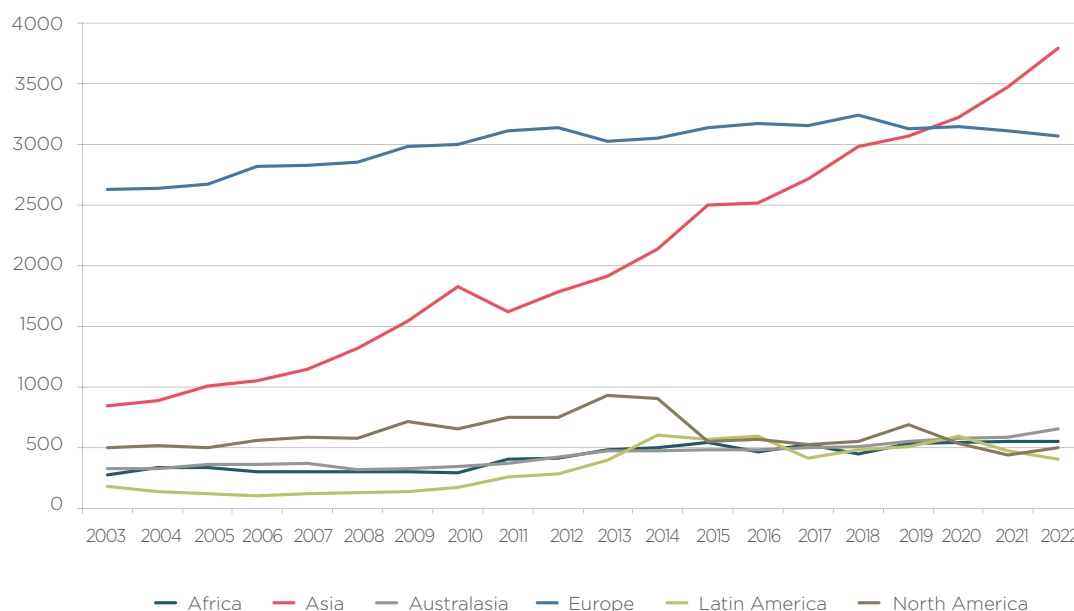
	Individual Members	Corporate Members	National Groups
Africa	549	1	3
Asia	3795	72	12
Australasia	655	6	2
Europe	3070	81	30
Latin America	406	3	9
North America	498	4	2
<b>TOTAL</b>	<b>8973</b>	<b>167</b>	<b>58</b>

From the total number of 8973 individual members, 8903 are registered through their respective National Groups and 70 are corresponding members. When compared with the figures from the previous year, they correspond to an increase of 344 individual members (4%). The number of corporate members has decreased by 3. The main increase in the number of individual members was registered in China.

In November, the Sri Lankan Rock Mechanics and Engineering Society – SLRMES was approved as the new ISRM National Group of Sri Lanka, with 10 ordinary members.

The following graphic shows the evolution of the number of individual members in each geographic region since 2003.

Individual members per region



## 2 - ADDITIONAL ISRM BOARD VIDEOCONFERENCES

On 12 May the Board held one 3-hour videoconference to complement the annual Board meeting and to discuss important issues for the Society.

## 3 - ISRM BOARD, COUNCIL, AND COMMISSIONS MEETINGS OF 2022

Despite the difficult times the world is living due to the persistence of the Covid-19 pandemic and the economic constraints observed in 2022, the Board, Council and Commissions of the ISRM met in Asunción, Paraguay, during the ISRM International Symposium LARMS2022.

- Prof. Derek Martin, from Canada was selected as the recipient of the 9th Müller Award and will receive the award and deliver the Müller Lecture during the 2023 ISRM International Congress, in Salzburg, Austria.
- Seoul, Korea was selected as the venue for the 16th ISRM International Congress, in 2027.

## 4 - ISRM SPONSORED MEETINGS

Since the last Council meeting on 17 November 2021 as a videoconference, the following conferences took place:

- TuniRock 2022; 26-28 March, Hammamet, Tunisia
- 5th Symposium of the Macedonian Association for Geotechnics, 23-25 June, Ohrid, Macedonia
- RocDyn-4, 17-19 August, Xuzhou, China
- SBMR – 9th Brazilian Rock Mechanics Symposium, 23-26 August, Campinas, Brazil
- Eurock 2022, 12-15 September, Helsinki, Finland
- LARMS2022 – an ISRM Regional Symposium – 16-19 October 2022, Asuncion, Paraguay
- CouFrac 2022 – an ISRM Specialized Conference – 14-16 November 2022, Berkeley, USA
- ARMS12 – an ISRM Regional Symposium – 22-26 November 2022, Hanoi, Vietnam
- AusRock 2022 – an ISRM Regional Symposium – 29 November-1 December 2022, Melbourne, Australia

The following ISRM sponsored conferences are scheduled:

- NROCK2023: The IV Nordic Symposium on Rock Mechanics and Rock Engineering – an ISRM Specialized Conference, 24-26 May 2023, Reykjavik, Iceland
- 3rd JTC1 Workshop on Impact of global changes on landslide risk, 7-10 June 2023, Oslo, Norway
- 10th Nordic Grouting Symposium – an ISRM Specialized Conference – 11-13 September 2023, Stockholm, Sweden
- 15th ISRM International Congress on Rock Mechanics, 9-14 October 2023, Salzburg, Austria
- Eurock 2024 – an ISRM Regional Conference, 15-19 July 2024, Alicante, Spain
- ARMS13 – an ISRM Regional Conference, 24-28 September 2024, New Delhi India

## 5 - ROCHA MEDAL

For the Rocha Medal Award in 2023, 19 applications were received. The Rocha Medal Committee selected the winner of the Rocha Medal 2023 prize and two Proxime Accessit (runner-up) certificates.

Submission of applications for the Rocha Medal 2025 is open until 31 December 2023.

- Rocha Medal 2023: Jun Zhao, from China, was selected as the winner of the Rocha Medal 2023, with the thesis entitled “Study on time-dependent failure mechanism and long-term stability of hard rock in deep buried tunnels” presented at the Northeastern University, China, and supervised by Xia-ting Feng.
- Runner-up certificate: Rupesh Verma, from India, was awarded a runner-up certificate for the thesis “A combined theoretical-experimental-numerical approach to characterization and modelling of rock fracture and rock burst” presented at the University of Adelaide, Australia and supervised by Giang D. Nguyen.
- Runner-up certificate: Cyrille Couture, from Canada, was awarded a runner-up certificate for the thesis “Mechanical characterization of porous sandstones in true triaxial conditions: diffuse and localized deformation, effect of anisotropy” presented at the Université Grenoble Alpes, France and supervised by Pierre Bésuelle.

## 6 - ISRM AWARDS

In 2022 the following awards were conferred:

- John Hudson Rock Engineering Award awarded to Dr Christine Detournay, from the USA
- Science and Technology Awards - Science Achievement Award, awarded to Prof. Jean Sulem, from France
- Young Rock Engineering Award awarded to Dr Yota Togashi, from Japan

## 05 7 - INDUCTION OF ISRM FELLOWS

Five new ISRM Fellows, selected by the Board, were inducted during the International Symposium Eurock2021, and the corresponding medals and certificates were handed over during the ISRM International Symposium LARMS2022, in October 2022, in Asunción, Paraguay.

Manchao He, from China

Eda Freitas de Quadros, from Brazil

Luís Ribeiro e Sousa, from Portugal

Doug Stead, from Canada

Håkan Stille, from Finland

## 8 - ISRM MULTILINGUAL GLOSSARY ON ROCK MECHANICS

The multilingual glossary of rock mechanics technical terms is available on the ISRM website since March 2015, under the item "Products and Publications. The translation into 19 different languages has been achieved, Mongolian being the most recent language available.

## 9 - ISRM NEWS JOURNAL

The electronic version of the ISRM News Journal, Vol. 24, December 2021, edited by the ISRM President, Prof. Reşat Ulusay and Dr José Muralha, was uploaded on the ISRM website, where it can be read and downloaded. The Secretariat sent info-mails to all members, advertising it. 450 hard copies were printed for distribution during the ISRM sponsored conferences. This 84-page issue of the News Journal contains the annual review of the Society's activity along 2021 and technical articles related to the ISRM awards.

## 10 - ISRM NEWSLETTER

Since the 2021 Council meeting, five quarterly Newsletters, prepared by the Secretary General, were published: in December 2021, in March, June, September and December 2022. As usual, all ISRM members and all those that subscribed to the Newsletter on the website received them by email. The Newsletters are also available on the website. ISRM National Groups and individual members are welcome to submit to the Secretariat contributions on rock mechanics topics of interest to our technical community.

## 11 - ISRM WEBSITE

The website of the ISRM (<http://www.isrm.net>), launched on 1 April 2005, is the main means of information of the ISRM and the main channel for communication with the members. Most benefits being offered to the members are available in the password protected members' area. The information on the website has been continuously updated during the period corresponding to this report.

## 12 - ISRM YOUTUBE CHANNEL

The ISRM YouTube channel was launched in October 2021. It allows streaming of live events organised by

the ISRM with Zoom, Teams, etc.; Storage of videos and several types of channels can be created. The 1st and 2nd European Rock Mechanics Debate have been included in the channel.

Two new YouTube channels were created, linked to the main ISRM channel: the ISRM Commission on Deep Mining channel and the ISRM Young Members Channel.

## 13 - DIGITAL LIBRARY

The ISRM Digital Library started in October 2010 and is part of OnePetro.org, a large online library managed by the Society of Petroleum Engineers. ISRM individual members are allowed to download, at no cost, up to 100 papers per year from the ISRM conferences. ISRM corporate members can download 250 papers.

Papers from the ISRM Congresses and sponsored Symposia have been gradually introduced in the library. Currently, the papers from 68 ISRM sponsored events are available, totalling around 11.250 papers and 91,450 pages.

## 14 - ISRM ONLINE LECTURES

Since February 2013 the ISRM broadcast 40 ISRM Online Lectures, from the ISRM website, all given by prominent scholars. All lectures are kept in an appropriate page of the ISRM website. The December lecture by Prof. Charlie Chunlin Li was the last to be broadcast in 2021. In 2022 four other lectures were broadcast, by Prof. Prof. Yuzo Ohnishi, Prof. Zhou Yingxin, Emeritus Prof. Bruce Hebblewhite and Dr José Delgado Rodrigues.

## 15 - 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 other facilities offered to the Secretariat and telephone, as well as use of LNEC's computer network, namely for internet access. This support has long been instrumental to the well-being of the Society and is very much appreciated.

## 16 - FINAL REMARKS

ISRM activities were conditioned by Covid-19, but most of them did not stop. The life of the Society and the activity of the Secretariat during the period corresponding to this report were marked by:

- continuation of the increase in the number of members of the Society;
- update of the website;
- continuation of the upload of conference proceedings in the ISRM Digital Library;
- expansion of the activities through the Internet;
- maintenance of a sound financial situation. 🏆

Luís Lamas  
ISRM Secretary-General



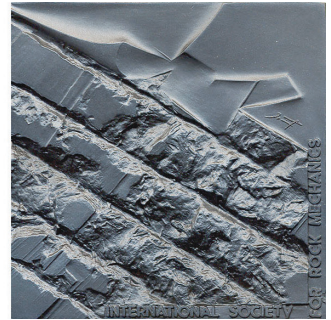
MEMBERSHIP IN  
OCTOBER 2022

REGION	NATIONAL GOUPS / Countries	Members		
		Ordin.	Corr.	Corp.
AFRICA	Angola		1	
	Botswana		1	
	Ghana		1	
	Kenya		2	
	Morocco		1	
	SOUTH AFRICA	518		1
	TUNISIA	10		
	ZIMBABWE	15		
TOTAL	3 NGs	543	6	1
ASIA	CHINA	2.762	5	27
	INDIA	230	3	
	INDONESIA	57	1	
	ISRAEL	20		
	JAPAN	304		36
	Kazakhstan		3	
	KOREA	180		8
	Korea DPR		3	
	MALAYSIA	54		1
	MONGOLIA	24		
	NEPAL	11		
	Philippines		2	
	Saudi Arabia		1	
	SINGAPORE	110	1	
	SOUTH EAST ASIA	11		
	Thailand		1	
	Un. Arab Emirates		1	
	VIETNAM	11		
TOTAL	13 NGs	3.774	21	72
AUSTRALASIA	AUSTRALIA	415	5	6
	NEW ZEALAND	235		
TOTAL	2 NGs	650	5	6
EUROPE	ALBANIA	11		
	AUSTRIA	378		2
	BELGIUM	58		
	BOSNIA AND HERZEGVINA	14		
	BULGARIA	32		
	CROATIA	105		
	CZECH REPUBLIC	26		
	DENMARK	15		
EUROPE	FINLAND	91	1	1
	FRANCE	124		9
	GERMANY	316	4	4
	GREECE	38	2	
	HUNGARY	18		
	ICELAND	12		
	Ireland		1	1
	ITALY	112	2	1
	MACEDONIA	10		
	NETHERLANDS	27		
	NORWAY	242		15
	Poland		3	
	PORTUGAL	86	1	5
	ROMANIA	17	2	
	RUSSIA	235	4	13
	SERBIA	17		
	SLOVAKIA	6		
	SLOVENIA	34	1	
	SPAIN	277	1	
	SWEDEN	117		18
	SWITZERLAND	146		9
	TURKEY	116	1	
	UKRAINE	8		
	UNITED KINGDOM	355	5	3
TOTAL	30 NGs	3.043	27	81
LATIN AMERICA	ARGENTINA	21		
	BOLIVIA	24		
	BRAZIL	71	3	
	CHILE	82	1	2
	COLOMBIA	11		
	COSTA RICA	21		
	MEXICO	32	1	
	PARAGUAY	39		
	PERU	95	3	1
	VENEZUELA		2	
TOTAL	9 NGs	396	10	3
NORTH AMERICA	CANADA	112	1	1
	USA	385		3
TOTAL	2 NGs	497	1	4
TOTAL ISRM	58 NGs	8.903	70	167



## ROCHA MEDAL 2025

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 researchers.



In addition to the Rocha Medal award to the winning submission, one or two runner-up certificates may also be awarded. An invitation is now extended to the rock mechanics community for nominations for the Rocha Medal 2025.

Full details about the Rocha Medal are provided in ISRM By-law No. 7, and all relevant information can be obtained from the ISRM website - [ismr.net](http://ismr.net).

### 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 sent electronically, addressed to the Secretary-General, and shall contain:

- a one page curriculum vitae, including nationality information;
- a written confirmation by the candidate's National Group that he/she is a member of the ISRM;
- a thesis summary, 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, and information on word count;

- one copy of the complete thesis;
- 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 2023.

### Past Recipients

1982	A.P. Cunha	PORTUGAL	2003	L.M. Andersen	SOUTH AFRICA
1983	S. Bandis	GREECE	2004	G. Grasselli	ITALY
1984	B. Amadei	FRANCE	2005	M. Hildyard	UK
1985	P.M. Dight	AUSTRALIA	2006	D. Ask	SWEDEN
1986	W. Purrer	AUSTRIA	2007	H. Yasuhara	JAPAN
1987	D. Elsworth	UK	2008	Z.Z. Liang	CHINA
1988	S. Gentier	FRANCE	2009	G. Li	CHINA
1989	B. Fröhlich	GERMANY	2010	J.C. Andersson	SWEDEN
1990	R.K. Brummer	SOUTH AFRICA	2011	D. Park	REP. OF KOREA
1991	T.H. Kleine	AUSTRALIA	2012	M.T. Zandarin	ARGENTINA
1992	A. Ghosh	INDIA	2013	M. Pierce	CANADA
1993	O. Reyes W.	PHILIPPINES	2014	M.S.A. Perera	AUSTRALIA
1994	S. Akutagawa	JAPAN	2015	A.L. Bradley	ITALY
1995	C. Derek Martin	CANADA	2016	C.W. Boon	MALAYSIA
1996	M.P. Board	USA	2017	Bryan Tatone	CANADA
1997	M. Brudy	GERMANY	2018	M. du Plessis	SOUTH AFRICA
1998	F. Mac Gregor	AUSTRALIA	2019	Q. Lei	CHINA
1999	A. Daehnke	SOUTH AFRICA	2020	J. Shang	CHINA
2000	P. Cosenza	FRANCE	2021	Y. Yasuhiro	JAPAN
2001	D.F. Malan	SOUTH AFRICA	2022	R.S. De Silva	SRI LANKA
2002	M.S. Diederichs	CANADA	2023	J. Zhao	CHINA

THE 2022  
ISRM YEAR

## EVENTS

January	- 1st Young Members' online Seminar
February	- 2nd Young Members' online Seminar
March	<ul style="list-style-type: none"> <li>- Launching of the ISRM Survey 2022</li> <li>- ISRM Specialized Conference TuniRock 2022, in Hamammet, Tunisia</li> <li>- 37th ISRM Online Lecture by Prof. Yuzo Ohnishi: "Evolution of numerical methods for coupled problems in rock mechanics and engineering"</li> <li>- Publication of the 2021 issue of the News Journal and of the e-Newsletter No. 57</li> <li>- 3rd Young Members' online Seminar</li> </ul>
April	<ul style="list-style-type: none"> <li>- Meeting of the FedIGS Board</li> <li>- 4th Young Members' online Seminar</li> </ul>
May	<ul style="list-style-type: none"> <li>- Interim meeting of the ISRM Board</li> <li>- 5th Young Members' online Seminar</li> </ul>
June	<ul style="list-style-type: none"> <li>- ISRM Specialized Conference 5th Symposium of the Macedonian Association for Geotechnics, in Ohrid, Macedonia</li> <li>- 38th ISRM Online Lecture by Prof. Yingxin Zhou: "The Rock Engineering Process (for Cavern Construction)"</li> <li>- Publication of the e-Newsletter No. 58</li> <li>- 6th Young Members' online Seminar</li> </ul>
July	- 7th Young Members' online Seminar
August	<ul style="list-style-type: none"> <li>- ISRM Specialized Conference RocDyn-4: 4th International Conference on Rock Dynamics, in Xuzhou, China</li> <li>- ISRM Specialized Conference SBMR2022: 9th Brazilian Rock Mechanics Symposium, in Campinas, Brazil</li> <li>- 8th Young Members' online Seminar</li> </ul>
September	<ul style="list-style-type: none"> <li>- ISRM Regional Symposium Eurock 2022: Rock and Fracture Mechanics in Rock Engineering and Mining, in Helsinki, Finland</li> <li>- 39th ISRM Online Lecture by Prof. Bruce Hebblewhite: "Non-conventional surface subsidence – a challenge for an improved fundamental understanding"</li> <li>- Publication of the e-Newsletter No. 59</li> </ul>
October	<ul style="list-style-type: none"> <li>- ISRM International Symposium LARMS2022: Challenges in Rock Mechanics: Towards a Sustainable Development of Infrastructure</li> <li>• Dr Radhika De Silva, from Sri Lanka, delivered the 2022 Rocha Lecture</li> <li>• Dr Werner Bilfinger, from Brazil, delivered the 2022 Franklin Lecture</li> <li>• Doug Stead, Eda Quadros, Håkan Stille, Luís Ribeiro e Sousa and Manchao He received the 2021 ISRM Fellows medals and certificates</li> <li>• 9 young members from the Latin American region were invited to make presentations in the 7th edition of the ISRM Early Career Forum</li> <li>• 8 international teams participated in the RockBowl competition</li> <li>- ISRM Board and Council meetings</li> <li>• Dr Jun Zhao, from China, was selected as recipient of the Rocha Medal 2023</li> <li>• The audited accounts of 2021 and budget for 2023 were approved by the Council</li> <li>• Prof. Derek Martin, from Canada, was selected as the recipient of the 9th Müller Award.</li> <li>• New Delhi, India, was selected as the venue for the 2024 ISRM International Symposium</li> <li>• Seoul, Korea, was selected as the venue for the 16th ISRM International Congress, in 2027</li> <li>• Salzburg, Austria, was confirmed as the venue for the 2023 16th ISRM International Congress</li> <li>- 10th Young Members' online Seminar</li> </ul>
November	<ul style="list-style-type: none"> <li>- ISRM Specialized Conference CouFRac 2022: International Conference on Coupled Process in Fractured Geological Media: Observation, Modeling and Application, in Berkeley, USA</li> <li>- ISRM Regional Symposium ARMS12: 12th Asian Rock Mechanics Symposium, in Hanoi, Vietnam</li> <li>- 11st Young Members' online Seminar</li> </ul>
December	<ul style="list-style-type: none"> <li>- ISRM Regional Symposium AusRock 2022: 6th Australasian Ground Control in Mining Conference, in Melbourne, Australia</li> <li>- 40th ISRM Online Lecture by Dr José Delgado Rodrigues: "Stone in Cultural Heritage – From the rock mass to the stone piece"</li> <li>- Publication of the e-Newsletter No. 60</li> <li>- 12nd Young Members' online Seminar</li> </ul>



## 07 ONLINE LECTURE SERIES

The ISRM Online Lectures Series have been running in a trimestral basis uninterruptedly since February 2013. In 2022 another four high-level lectures were broadcast from the ISRM website at a preannounced date and time. The complete series of online lectures remain available for all interested to watch in the ISRM website ([isrm.net/page/show/138?tab=1104](https://isrm.net/page/show/138?tab=1104))



37th ISRM online lecture, March 2022

**Prof. Yuzo Ohnishi**

Evolution of numerical methods for coupled problems in rock mechanics and engineering

Natural rock masses consist of solid and fluid materials (water, air, others). In rock mechanics and engineering, researches have made an effort to understand rock mass behavior under different mechanical and hydraulic conditions. The study of rock and fluids interaction is extremely diverse and forms a typical interdisciplinary area. For example, the rock slope fails due to heavy rain, which is the typical interaction between rock and water (coupling). In this stress-flow coupling problem, the basic equations for the water flow and for the stress-deformation are solved simultaneously, using a concept of “effective stress principle”. As a result, flow and stress deformation has been integrated, and the coupling solutions can be applied in practice.

The advancement of (Thermal)H(Hydraulic) M(Mechanical)C(Chemical) analyses is largely due to the DECOVALEX project, a collaborative research host on the geological disposal of high-level radioactive wastes. Fully coupled THM analysis becomes common and chemical and time effect is under consideration.

The major problem of THMC for rock mass is its modeling and analysis method. The analysis method changes greatly depending on how to model the rock and the fluid present in it. Numerical methods (mainly FEM) to handle the coupled problems keep on evolving. While changing from continuum to discontinuous medium analysis, discrete methods such as DEM, DDA etc. were developed and DFN models have been introduced.

The quality of input data in analyses is also important. In numerical analysis, modeling (geometrical features) of the target medium and physical property values are crucial. As models become more complex, input parameters increase, and advanced experiment and proper judgment are required to determine the parameters. The importance of monitoring has been particularly strong. Various high-performance measuring devices have been developed, and real-time data acquisition has become possible through the Internet. Developing the analysis and measurement methods in cooperation with each other will create synergetic effects, and further understanding of coupling behavior of rock mass will be achieved.



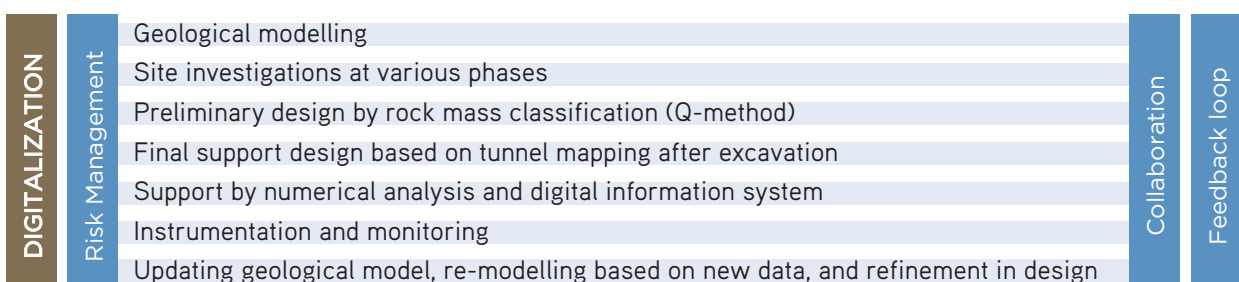
38th ISRM online lecture, June 2022

**Prof. Zhou Yingxin**

The Rock Engineering Process (for Cavern Construction)

Rock engineering is highly empirical due to the inherent geological uncertainties, and our limited ability to understand, test, and measure rock mass properties and rock mass behaviour at scale. It is argued that the greatest risk in rock engineering is not geology – it is people (studies suggest more than 80% of the tunnel failures are due to human errors). The best approach to minimising human errors and risks and ensure consistent quality and safety is to follow a systematic engineering process.

This process begins with the big picture – the geological model, which guides the site investigations and risk management. In turn, site investigations help validate and improve the geological model. Site investigations are planned and carried out during different phases



of the project. Support design is based on rock mass classification such as the Q-system, and supported by numerical modelling, instrumentation and monitoring. The geological and numerical models are continually updated with new mapping data, and the design is optimised. Collaboration and feedback are



39th ISRM online lecture, September 2022

**Emeritus Prof. Bruce Hebblewhite**

Non-conventional surface subsidence – a challenge for an improved fundamental understanding

The lecture deals with issues related with subsidence above underground coal mines. Subsidence is a well-known phenomenon that causes deformation of the ground mass, including all mining-induced displacements. It can be related to several parameters, such as vertical and horizontal strata deformation, strata failure, shearing, strata unit bending, bedding plane shear, tensile and compressive strains, tilt, and subsidence effects within the angle of draw. Subsidence impacts are the physical changes to the ground and its surface, and they may lead to serious environmental consequences: loss of surface water flows, loss of standing pools, groundwater quality, adverse surface, cliff falls or rock falls, development of iron bacterial mats.



40th ISRM online lecture, December 2022

**Dr José Delgado Rodrigues**

Stone in Cultural Heritage - From the rock mass to the stone piece

Rocks and rock masses have long been associated with Humans. They provided the first shelters, were used in the first weapons and were integrated into the first constructions. The long durability of the stone materials allowed to preserve and transmit the first signs of Human creativity to reach us, and many of the best examples of cultural manifestations of the past are inscribed in stone.

Rock masses provide materials for Human undertakings, either for common constructions as rock fill dams and transportation infrastructures, but also for building imposing cathedrals and sculpting delicate art works. The same or similar material can be used in them, but the significance that the works have for the

essential, with risk management permeating the entire process. The collaborative process involves all key stakeholders and ensures open and timely discussion and communications, and integration of the design and construction issues, which include client's requirements, quality control, and safety management.

Though widely understood, an adequate assessment requires a well defined terminology, and so the definitions of anomalous, systematic, conventional and non-conventional subsidence are defined.

The main topic of the lecture is non-conventional subsidence, which is defined a particular behaviour, normally associated with irregular surface topography, resulting in effects and impacts that can be systematic in nature, but are not described by conventional subsidence models, and include far-field movements, valley closure and valley-floor upsidence. An extensive body of evidence of these phenomena has been gathered in the Southern Coalfield of New South Wales, Australia.

The lecture features a number of interesting, illustrative examples: the Tower Colliery and Nepean Cataract Gorges, the Dendrobium mine and Sandy Creek waterfall, the Ryerson Station reservoir, and the Broadmeadow Punch longwall.

The lecture concludes that there is an extensive site-specific data that permits reasonable prediction of subsidence behaviour, but a more rigorous and universally applicable mechanism model that explains the behaviour and leads to better predictions is still needed.



community to which they belong makes a difference. The Geotechnical field deals with the utilitarian values of the undertaking, while the cultural values are dealt with by the professional field of Conservation and Restoration. In Geotechnical works, materials are understood in statistical terms, while in Cultural Heritage objects each piece matters and the elements have their own "identity".

Examples will be presented to show that material properties impact differently in both fields and to illustrate that adaptation of common technologies needs to be done to deal with the specifics of Cultural Heritage problems. 🚩

## 07 ISRM COMMISSIONS

The objective of ISRM Commissions is to study scientific and technical matters of interest to the Society. In recognition of the critical role of the ISRM Commissions, the ISRM Board created a committee – the Technical Oversight Committee (TOC) to coordinate the commission's work, report on their performance and to act as oversight for the Commissions. Since ISRM Commissions are appointed by the Board for each 4-year period between ISRM Congresses. Establishment of new Commissions or the continuation of pre-existent ones is decided by the new Board following proposal by the TOC.

By the end of 2022 there were 15 ISRM technical commissions involving 266 commission members from 36 different national groups working arduously. Various kinds of activities conferences, meetings, workshops, courses, forums, publication of relevant journal special issues and ISRM Suggested Methods are planned by the Commissions for the next years.

COMMISSION	ESTABLISHED
Coupled Thermal-Hydro-Mechanical- Chemical Processes in Fractured Rocks	2018
Crustal Stress and Earthquakes	2011
Deep Mining	2019
Design Methodology	pre 2004
Discontinuous Deformation Analysis	2011
Planetary Rock Mechanics	2019
Radioactive Waste	2010
Rockbursts	2019
Rock Dynamics	2007
Rock Grouting	2019
Soft Rocks	2019
Sorptive Rocks	2021
Testing Methods	circa 1970
Underground Nuclear Power Plants	2012

Based on the assessments done by TOC on the performance of the commissions showed that the majority of the commissions are performing at a high level or at a sufficient level with no major concerns. Following the suggestion of the TOC, the ISRM Board decide to end the appointment of the Commission on the Preservation of Ancient Sites.

Dealing with topics of mutual interest, three Joint Technical Committees work under the umbrella of the Federation of International Geo-Engineering Societies - FedIGS, which joins the efforts of the Sister Societies IAEG, IGS, ISRM and ISSMGE. The current list of JTCs is the following:

JTC 1 - Joint Technical Committee on Natural Slopes and Landslides

JTC 2 - Representation of Geo-engineering Data in Electronic Form

JTC 3 - Education and Training





## ISRM VIDEO COURSES

Following the rapid increase in the use of virtual tools that took place in previous years, two new video courses were made available to the general public on the ISRM website.

### "COURSE ON CRUSTAL STRESS ASSESSMENT AND ITS APPLICATION IN ENGINEERING AND EARTHQUAKE RESEARCH"

by members of the ISRM Commission on Crustal Stress and Earthquakes

In order to improve the methods and techniques of borehole-based stress-strain observatory, especially for calibration technology, promote experimental studies on deep-borehole stress measurement, and advance research collaboration associating the crustal stress with seismicity, seismogenesis, and rock failure process, the ISRM Commission on Crustal Stress and Earthquakes invited five commission members to present a video course. This course includes two parts on the technology of in-situ stress measurement and its applications in engineering, two parts on the technology of borehole tensor strainmeter and its calibration, and one part on the application of the crustal stress in Earthquake research:

Part 0 - Furen Xie - Course Presentation (15 minutes)

Part 1 - Hong Li - Realization of multi-component and 3-D borehole strain-meter observation technology (30 minutes)

Part 2 - Takatoshi Ito - Core deformation: A new stress indicator applicable in a wide range of depth and temperature (45 minutes)

Part 3.1 - Zhongqi Quentin Yue - Methane gas refined fault theory for cause of tectonic earthquakes (two hours)

Part 3.2 - Zhongqi Quentin Yue - Methane gas refined fault theory for cause of tectonic earthquakes (two hours)

Part 3.3 - Zhongqi Quentin Yue - Methane gas refined fault theory for cause of tectonic earthquakes (two and a half hours)

Part 4 - Qunce Chen - In situ stress measurements around Eastern Himalayan syntaxis (30 minutes)

Part 5 - Jiayong Tian - Dynamic calibration of borehole tensor strainmeters (45 minutes)

### "ROCKBURST IN DEEP TUNNELS"

by Xia-Ting Feng

Prof. Xia-Ting Feng (ISRM President from 2011 to 2015) presents this three and a half hours video course on Rockburst in Deep Tunnels. In order to improve the understanding of the rockburst in deep tunnels, it consists of nine parts, specifically addressing the types, intensity, influencing factors, microseismic monitoring, mechanism, dynamic warning, and rockburst risk mitigation. Finally, typical scenarios are provided from the viewpoint of deep engineering practice.

Part 1 - Introduction to Rockbursts

Part 2 - Types and Intensity of Rockbursts

Part 3 - Factors Influencing Rockbursts

Part 4 - Microseismic Monitoring of Rockburst Development Process

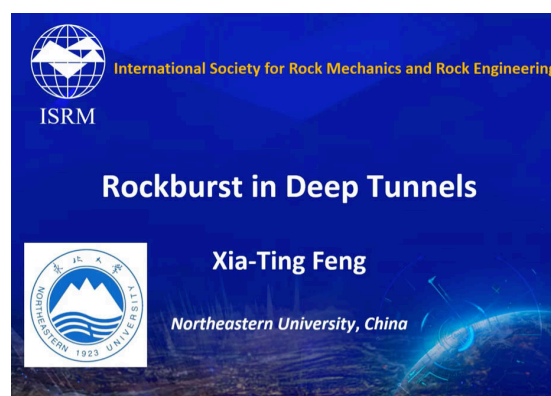
Part 5 - Mechanism of Rockbursts in Deep Tunnels

Part 6 - Dynamic Warning of Rockbursts in Tunnels

Part 7 - Rockburst Risk Mitigation in Deep Tunnels

Part 8 - Application in Deep Headrace TBM Tunnels

Part 9 - Application in Deep Railway Drill and Blast Tunnels



Crustal Stress Assessment and Its Application in Engineering and Earthquake Research

### Introduction to video course on Crustal Stress Assessment and Its Application in Engineering and Earthquake Research



**Furen Xie**

1. President, ISRM Commission on Crustal Stress and Earthquake
2. National Institute of Natural Hazards, Ministry of Emergency Management of P.R.China, Beijing, 100085, P.R.China

## 07 AWARDS

### JOHN HUDSON ROCK ENGINEERING AWARD

The John Hudson Rock Engineering Award was given to Dr Christine Detournay, from the United States of America. It is an award instituted to honour the memory of Professor John Hudson, ISRM President from 2007 to 2011. This award is conferred by the ISRM President in recognition of achievements in engineering practice, such as developing an outstanding rock engineering project, designing and/or completing an outstanding rock engineering project, contributing to solving important practical rock engineering problems, effectively introducing to current rock engineering practice new and important technologies, promoting good practices with innovative technologies and management to reduce time and cost of a rock engineering project, or promoting good practices with innovative technologies and management to enhance health

Christine Detournay started working as a consultant for Itasca in 1993, where she is now a Principal Engineer. She holds a Geoengineering degree from the University of Liège, Belgium and a MSc and PhD degrees in Civil Engineering from the University of Minnesota. Her expertise is in the development of numerical models for application to coupled fluid-thermo-mechanical problems. She has contributed in the development of several Itasca codes, including FLAC, FLAC3D, 3DEC, and XSite. She is a principal developer for the groundwater-flow and thermal logic in FLAC3D and has been involved in the implementation of several of the constitutive models available with Itasca continuum codes. She has worked in consulting and development for various projects related to the oil and gas industry, including hydraulic fracturing, as well as on projects pertaining to underground waste repository, geothermal applications, slope stability, soil liquefaction and CO<sub>2</sub> sequestration. She has co-authored more than 65 publications, including conference papers, journal papers, and book chapters. She is co-editor of Proceedings Int. FLAC/DEM symposia.

Recently, she delivered the 35th ISRM online lecture entitled "Findings from Numerical Modeling at the site of a High Dam on the Jinsha River", and as recipient of the ISRM John Hudson Rock Engineering Award 2022 she contributed with a technical paper entitled "Contributing to solving important practical rock engineering problems" to this issue of the News Journal.



### 35<sup>th</sup> ISRM Online Lecture

10 a.m. GMT – 16 September 2021

#### "Findings from Numerical Modeling at the Site of a High Dam on the Jinsha River"

by

Dr. Christine Detournay

Principal Engineer, Itasca Consulting Group



### SCIENCE ACHIEVEMENT AWARD

The Science Achievement Award was conferred to Prof. Jean Sulem, from France. It is an award by the ISRM President, on a bi-annual basis, in recognition of contributions to the progress of the science of rock mechanics by making an important advancement of knowledge or by proposing and confirming a new theory to explain certain phenomena.

Jean Sulem is presently Professor of Rock Mechanics and Research Director at the École des Ponts – ParisTech, Director of the Laboratoire Navier, Université Gustave Eiffel, CNRS, Editor-in-Chief of Rock Mechanics and Rock Engineering, member of the Steering Committee of the M/HM Underground Laboratory (ANDRA), and member of the Board of Directors of the ALERT Geomaterials network. He has more than 240 publications including two books and three patents, edition of two collective



books, four special issues of international scientific journals, 120 journal papers or book chapters, and 123 papers in proceedings of international conferences. He has delivered several keynote lectures in major rock mechanics conferences, such as the 13th ISRM International Congress 2015, in Montreal (Canada), Eurock 2010, in Lausanne (Switzerland), and Eurock 2017, in Ostrava (Czech Republic). He was the President of the French NG of the International Society of Rock Mechanics from 2016 to 2020, and he contributed to the ISRM Online Lecture Series with its 10th edition entitled "Multiphysics Couplings and Stability of Fault Zones".

Jean Sulem provided major scientific contributions in all research fields he has worked, namely Rock mechanics experimental and constitutive modelling, strain localization and bifurcation phenomena in geomechanics, thermo-hydro-mechanical couplings in geomaterials, and petroleum geomechanics. He has brought seminal contributions in the analysis of time dependent behavior of deep tunnels and in the understanding and modelling of failure and instabilities of rocks as a bifurcation phenomenon. The convergence law proposed in his PhD thesis has allowed distinguishing between the effect of the face advance and of the delayed behavior of the rock mass on the time-dependent convergence of tunnels. Together with late Professor Vardoulakis, they published pioneering works on the analysis of strain localization phenomena in rock mechanics. Jean Sulem's contributions in the domain of fault mechanics mainly concern the effect of multi-physics couplings on seismic slip. They highlight the important role of thermal effects in pore fluid pressurization and onset of mineral decomposition as weakening mechanisms of the fault. Such phenomena enhance strain localization inside the fault core and subsequent stronger strength softening and slip acceleration. In the domain of petroleum geomechanics, Jean Sulem and co-authors have brought significant contributions in constitutive modelling of cement paste from hydration to hardened state in order to assess the cement sheath integrity in oil and gas wells.

## YOUNG ROCK ENGINEER AWARD



The Young Rock Engineer Award was conferred to Dr Yota Tagashi, from Japan. It is intended to acknowledge excellence in the field of rock engineering by ISRM individual members under 40 years old in early stages of their careers, in recognition of achievements in rock engineering practice, such as contributions to solve engineering

problems or develop original design solutions, to sustainable engineering practices, to the promotion of the engineering profession, or the pioneering use of materials and/or methods.

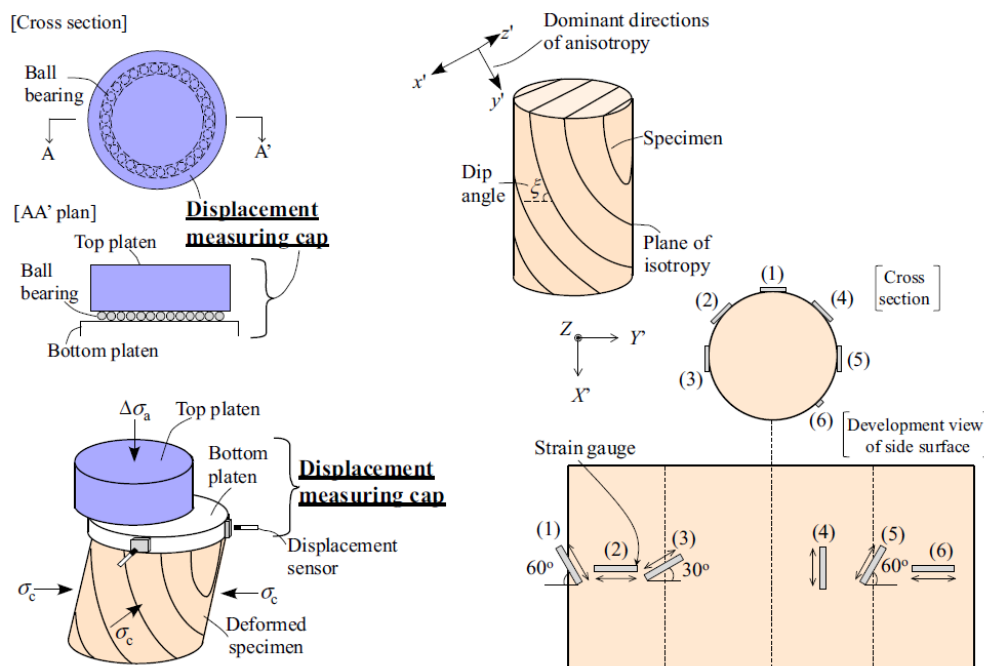
Yota Tagashi graduated in 2008 from the Yokohama National University, and got his Masters in 2011, which was followed by his Ph.D. in the School of Urban Innovation, with the highest honors, in 2014. He started his professional career at the Road Improvement Division of the Kanagawa Prefecture, between 2014 and 2018 he was a researcher at the Railway Technical Research Institute, and since 2018 he is Assistant Professor at the Rock Mechanics Laboratory, in the Saitama University.

He has published 60 peer-reviewed papers, he delivered seven invited lectures he got 13 patents, and he has participated as a member of 15 rock engineering society committees, such as the editorial board of Japanese Society Rock Mechanics, organizing committees of ISRM symposiums (YSRM & REIF 2019 and RMEGV 2021). He

has been awarded several distinctions, among which stand out the Technology Award from the Japanese Society of Rock Mechanics, and the Best Paper Award of the Japanese Geotechnical Society, both in 2016, the Best Paper Award for Young Professionals from the Japanese Geotechnical Society in 2028, and the Young Scientists' Prize, Commendation for Science and Technology by the Minister of Education of Japan in 2019.

In recent years, he has been dedicating his research to the relevant topic of evaluating the elastic constant of anisotropic rocks from compression tests. He has

paid particular attention to the determination of the elastic constants of transversely isotropic rocks using a single triaxial test, and to the influence of end restraints on the strain responses of anisotropic rocks during triaxial compression. ■





## 07 ISRM BOOK SERIES

The aim of the ISRM Book Series is to promote the scientific output of Rock Engineering topics. The Series is published according to the emergence of noteworthy scientific developments. Each volume in the Series is prepared independently and focuses on a topical theme. Since 2020 Profs. Xia-Ting Feng and Resat Ulusay act as Co-Editors-in-Chief. In 2021, the Series had one more release and the total number of books published in the Series became seven.

Most recently, a new book entitled "Underground Nuclear Power Plants, which was written by the ISRM Commission on Underground Nuclear Power Plants chaired by Prof. Shun Sakurai, was submitted to the publisher and will be published soon. The book consists of 18 chapters. Another book, written by Prof. Ömer Aydan entitled "Abandoned Room and Pillar Mines and Remediation Measures", was also submitted to the publisher and will be available in 2023. A third book concerning "Flow of Water in Fractured Rock Masses: Basic Theory & Practical Applications" is in preparation by Dr. Eda Quadros and Dr. Philippe Vaskou. 🇳🇵

## ONLINE ACTIVITIES

In addition to the Online Lecture Series, which is an initiative that has been going on continuously over the past 10 years, online activities are one of the key means of dissemination and communication between ISRM and its members, either by the YouTube Channel, or via the website. In 2022, the International Webinar on Rock Mechanics organized by young members of ISRM National Groups, which is described in detail in this issue in the Young Members Committee report, and the European Rock Mechanics Debates.



## EUROPEAN ROCK MECHANICS DEBATES

The European Rock Mechanics Debates aim at stimulating communication among academics and practitioners of rock mechanics and rock engineering in Europe. The debates are held online as zoom meetings and they are broadcast on the ISRM YouTube channel, where they can still be revisited. Each debate features two opponents with different perspectives on a hot rock mechanics topic or on a specific technical aspect of rock engineering.

The second European Rock Mechanics Debate on "What model for what application in rock mechanics" took place online on 9 June 2022 and was streamed to the ISRM YouTube channel, where it can be watched. It was chaired by Philippe Vaskou from France and featured the participation of Heinz Konietzky from Germany, talking about "From State-of-the-Art in Science towards Engineering Practice" and Jonny Sjöberg from Sweden talking about "Principles, Capabilities, and Strategies for Choosing Models". A flyer with the contents and indicative rules of these debates can be downloaded

**2<sup>ND</sup> ISRM EUROPEAN ROCK MECHANICS DEBATE (Eurock Debate 2)**

**Title:**  
**What model for what application in rock mechanics**

**Time:** 2022, June 9th, 3:00 PM (CET)- 1:00 PM (GMT)

**Links:** Here's the link for the Debate registration:  
(<https://us06web.zoom.us/joining/register/tZ1ec-ispj8u6tcNm3eDjP648XX8Nzjz3Opo>)

After registering, a confirmation email containing information about joining the meeting is sent. YouTube channel to directly follow:  
([https://youtube.com/channel/UcKnaR\\_zfPiNISIVJ-74pgfQ](https://youtube.com/channel/UcKnaR_zfPiNISIVJ-74pgfQ))

**Moderator: Philippe Vaskou (France)**

**Speaker 1: Heinz Konietzky (Germany)**  
**Subject: From State-of-the-Art in Science towards Engineering Practice**

The presentation will cover the following aspects: open-source versus commercial codes, trends & developments, model complexity, code coupling & optimization.

Bio: Prof. Dr. habil. Konietzky is Chair for Rock Mechanics and Rock Engineering at Freiberg University of Mining and Technology (TU Bergakademie Freiberg), Germany.

**Speaker 2: Jonny Sjöberg (Sweden)**  
**Subject: Principles, Capabilities, and Strategies for Choosing Models**

The presentation will cover the guiding principals and strategies for choosing type of model and codes, as well as the verification and validation of models.

Bio: Dr. Sjöberg is General Manager at Itasca Consultants AB, Sweden and Adjunct Professor Rock Mechanics and Rock Engineering at Luleå University of Technology, Sweden.

here. This second debate can be considered a success, with over 100 attendants. Other debates will follow and will be announced on the ISRM website. 🇳🇵

## IN MEMORY OF



**ÁLVARO  
GONZÁLEZ  
GARCÍA**  
1937 - 2022

It is with great sadness that the ISRM informs that Prof. Álvaro González García passed away on 9 February 2022, in Bogota. Prof. Álvaro González's professional career developed as a geotechnical engineer in projects related to roads, railways, hydroelectric projects, aqueducts and sewers, irrigation, mining, foundations, tunnels, sanitary fills, pavements and risks assessment.

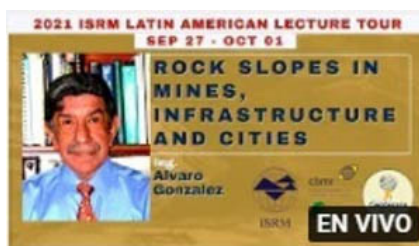
Alvaro Gonzalez graduated in Civil Engineer at the National University of Colombia and he was Master of Science at the University of London with various specialization courses. Besides working as a consultant in Análisis Geotécnicos

Colombianos AGC Ltda, he was Emeritus Professor of the National University of Colombia, published more than 120 papers and was member of the scientific committees of several international congresses.

Prof. González was active in the ISRM up until recently. In 2007 he was elected VP for South America and, very deservedly, he was appointed a Fellow of the ISRM in 2017. Prof. Álvaro González was a frequent participant in the ISRM Symposia, where he will be missed, and kept many friends in our Society, which remember his

kindness, his joyful attitude towards life and his great knowledge.

He was an excellent Engineer, Professor and remarkable Human Being who leaves us an important legacy. 🇨🇴



## FEDIGS

ISRM is one of the four international societies of the Federation of International Geo-Engineering Societies (FedIGS). FedIGS is a collaborative forum within which learned societies or associations involved in engineering with, on, or in geo-materials can meet and interact. The purpose of the Federation is to facilitate interaction among the member societies, explore opportunities to promote their common interests and provide a unified response to common issues through effective collective actions that are more effective than individual responses of the members. The four members of the federation are the International Society of Soil Mechanics and Geotechnical Engineering (ISSMGE), the International Society for Rock Mechanics and Rock Engineering (ISRM), the International Association of Engineering Geology and the Environment (IAEG) and the International Geosynthetics Society (IGS). The Board of FedIGS consists of the President, Immediate Past President and Secretary General of the four sister societies, and the President of the Federation is elected at every four years. Prof. Chungsik Yoo from Korea was elected this year as the new President of FedIGS; he took over the mission from Prof. Xia-Ting Feng, who was the ISRM Past President for the term 2011-2015.

The FedIGS Board created a number of Joint Technical Committees (JTC) and approved the JTC Guidelines. Current JTCs operating under the umbrella of the FedIGS are: JTC 1 – Natural Slopes and Landslides, JTC 2 – Representation of Geo-Engineering Data, and JTC 3 – Education and Training.

The 2022 annual meeting of the FedIGS Board was held on 21 September 2022 as an online meeting and ISRM was represented by its President, Immediate Past President and Secretary General. In this meeting. After the introduction by the FedIGS President, the Board members



Online meeting of 2022 FedIGS Board meeting

discussed the JTC reports presented by their respective chairmen. Regarding the report of JTC 1, it was suggested that the criteria for selecting lectures could be improved in the next actions. For JTC 2 it was agreed that all documents, reports and standard systems of JTC should be written in English and distributed to the societies, and that the JTC2 website should be linked to the FedIGS website.

In this meeting, it was acknowledged that FedIGS is the appropriate, common voice to suggest policy suited to provide sustainable development approaches to infrastructure development. Then it was decided that two Board members would develop a detailed proposal for a new Commission to be called "JTC on Environment and Geo-sustainability" and circulating it to the board. New initiatives of interaction between the member societies were accepted, namely FedIGS Planery Sessions, FedIGS Keynotes, FedIGS WhatsApp Group and FedIGS Forums. It was also decided to merge the event calendars of each society and respective website links, and place them on the FedIGS website. The next FedIGS meeting will be held in Salzburg, Austria, in October during the 15th ISRM Congress in 2023. 🇦🇹

## 07 2022 ISRM MEMBER'S SURVEY

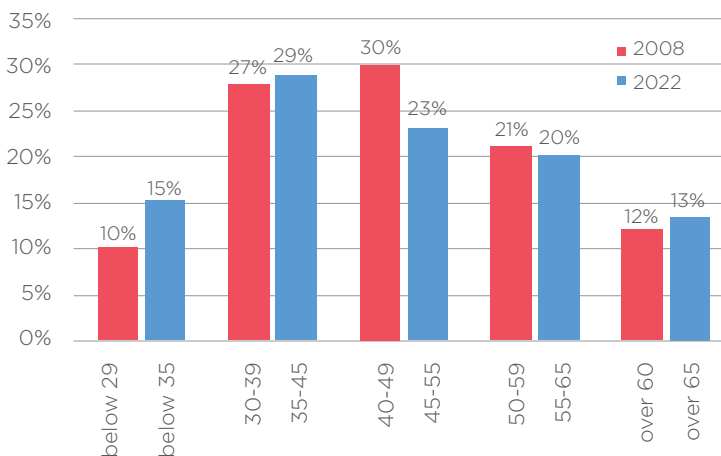
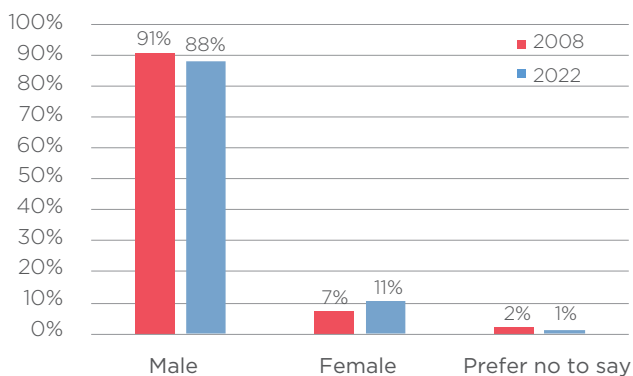
Sevda Dehkhoda, ISRM Vice-President for Australasia and YMC Chair

Only once in 2008 a survey to ISRM members was carried out. In 2021 the Young Members Committee prepared a new survey. It was released between March to April 2022 and distributed to ISRM members and non-members in 3 languages – English, Spanish, and Chinese. Overall, 737 people responded to the survey, 84% of which were members and 16% were non-members.

The goals of the survey were to understand the composition of the memberships, connect with the members and gauge their view of the society and gather thoughts on society's direction into the future. The survey also targeted to hear thoughts of younger demographics on how the society should respond for their needs.

This report provides an overview of the survey responses. The main conclusions are presented below.

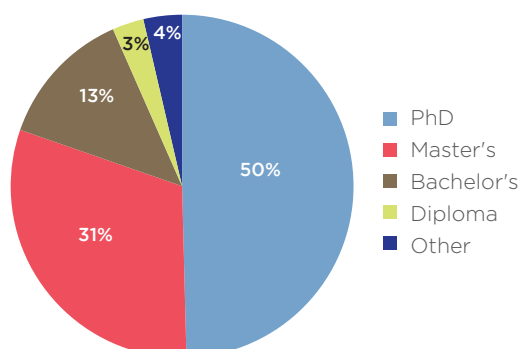
### MEMBER DEMOGRAPHICS



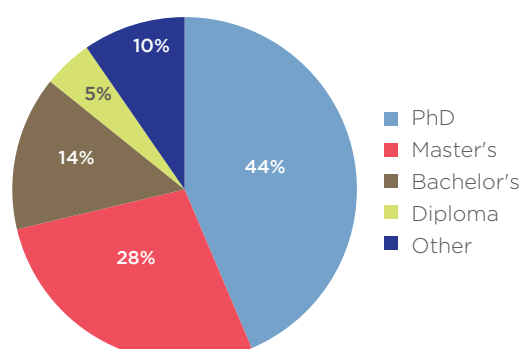
- There has been slight improvement in female participation.
- The society is aging.

## MEMBER EDUCATION

What is your highest level of education in general?



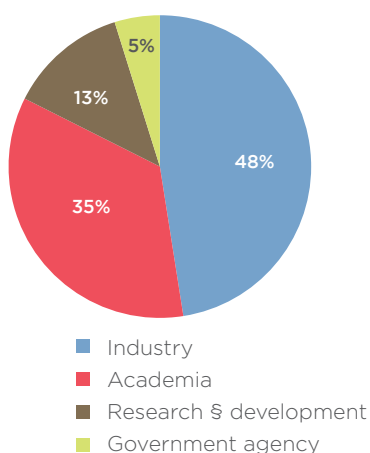
What is your highest level of education in Rock Mechanics and Rock Engineering?



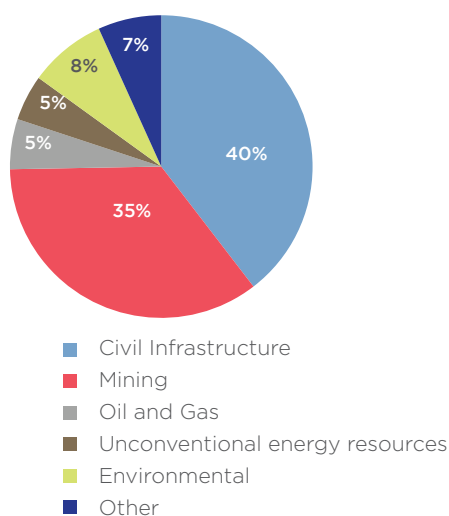
- ISRM serves highly educated members. 81% of the respondents had Master's or higher degree education.

## FIELD OF WORK AND STATUS

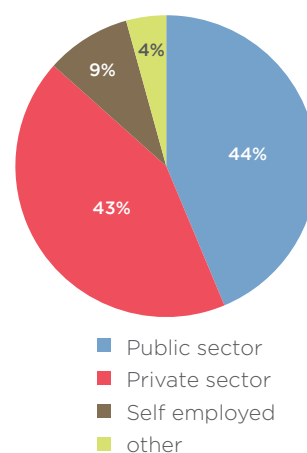
In which sector do you work?



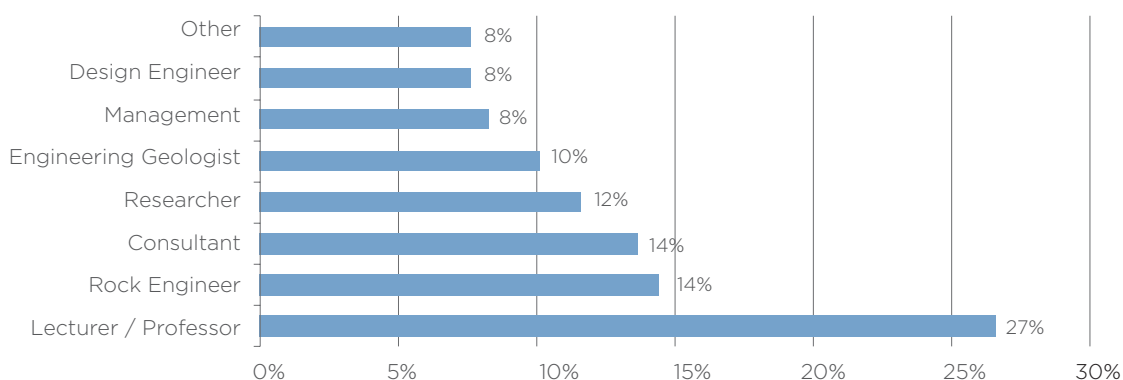
In which field do you work?



Who are you employed by?



What is your role in the organization?

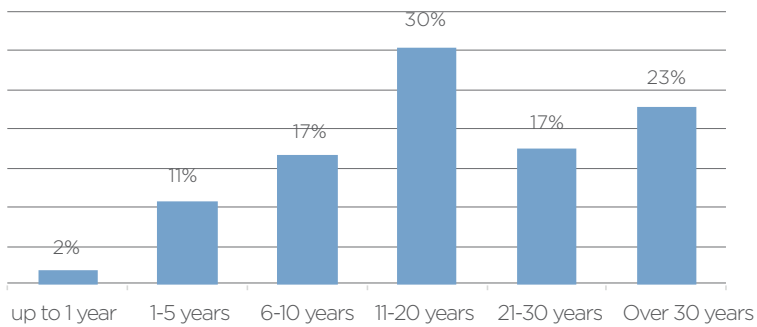


- Majority of the members worked for industry (48%) in civil infrastructure and mining fields in roles such as rock engineer and consultant.
- 35% of members worked in academia.

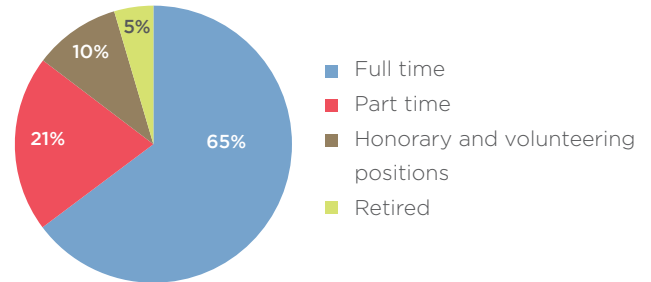


## 07 EXPERIENCE AND LONGEVITY

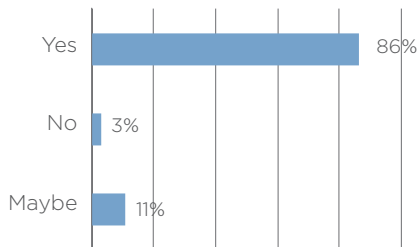
How long have you been working in Rock Mechanics and Rock Engineering?



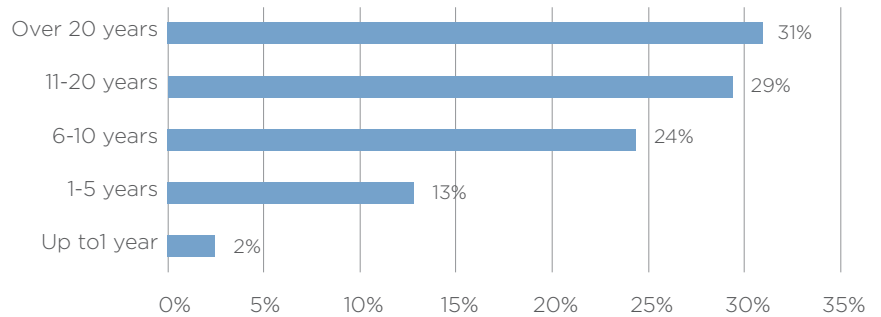
If you have been working in Rock Mechanics for more than 30 years, how would you define your working arrangements?



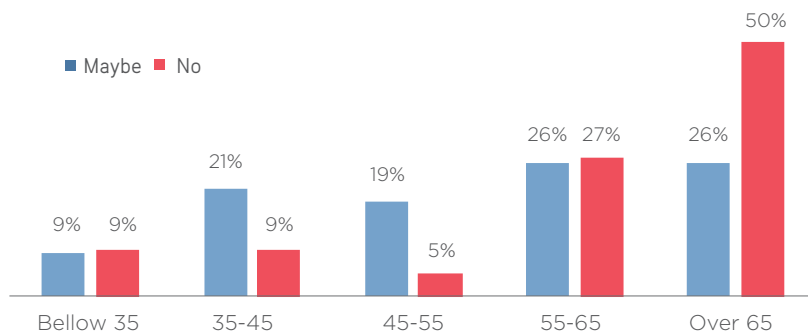
How many more years do you expect to be actively working in Rock Mechanics and Rock Engineering?



How many more years do you expect to be actively working in Rock Mechanics and Rock Engineering?



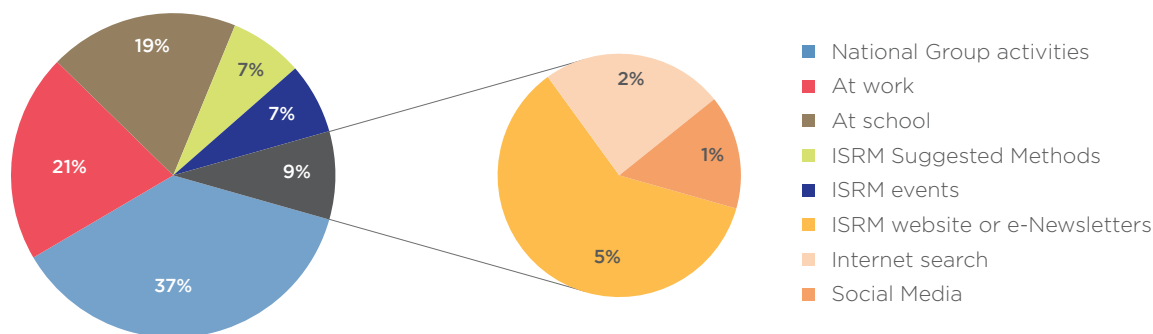
- Whilst society is aging, rate of attracting new members is too slow. Only 13% of the respondents were with less than 5 years into rock mechanics and rock engineering profession. This is whilst 23% of respondents had over 30 years of experience.



Age breakdown of respondents with "Maybe" and "No" Answer

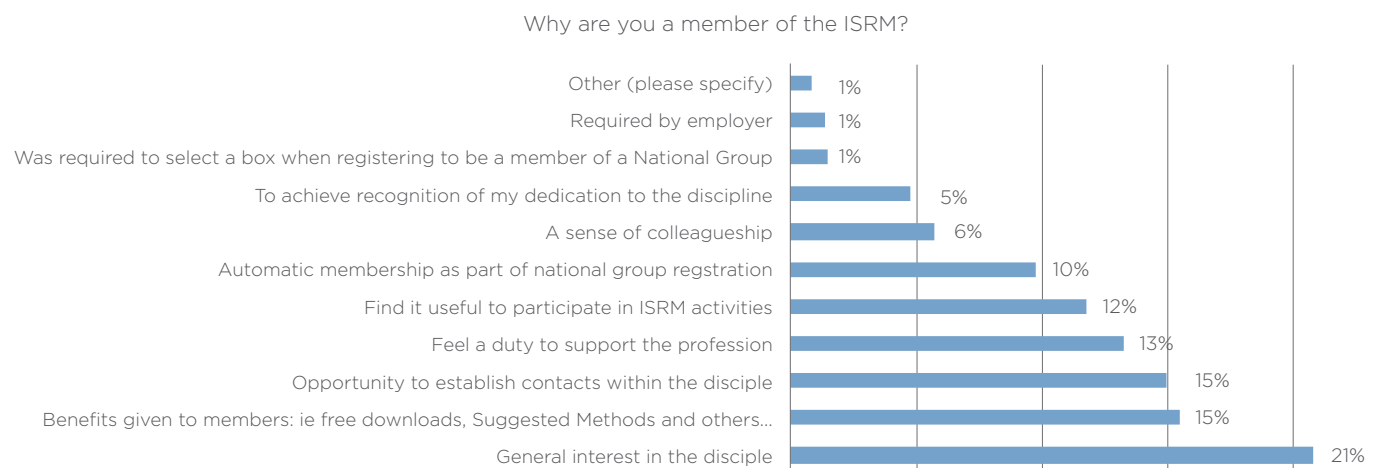
- Respondents with intention of not remaining in the profession expect to leave in the next 5 years. Majority of these respondents are in 'above 65' age group
- 30% of below 45 years old respondents are also unsure if they would remain in the profession

## ISRM - MEMBER ATTRACTION



- National Groups are how people mainly learn about ISRM, followed by word of mouth at work and school

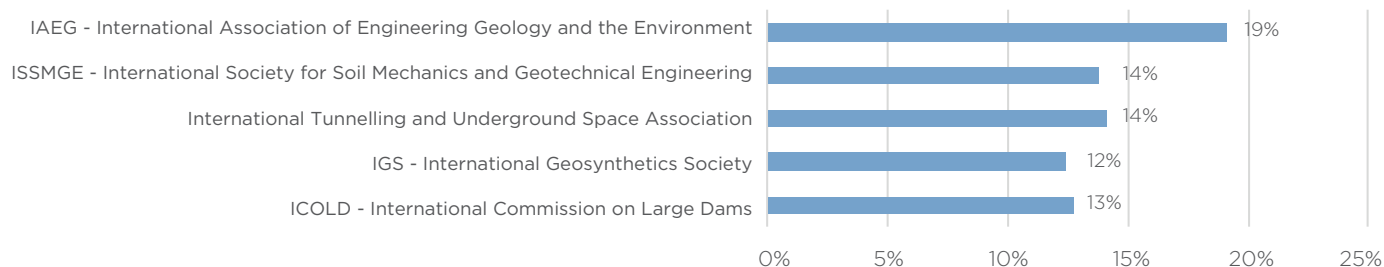
## MEMBER'S REASONS FOR JOINING ISRM



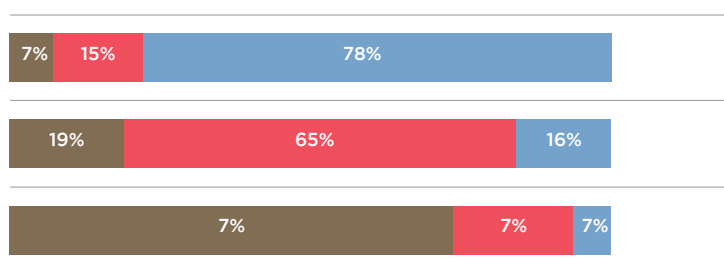
- General interest in Discipline seems to drive ISRM memberships.
- Given benefits and opportunity to build network are also big drivers to join the society
- Other reasons mentioned by respondents are:

## MEMBER ENGAGEMENTS

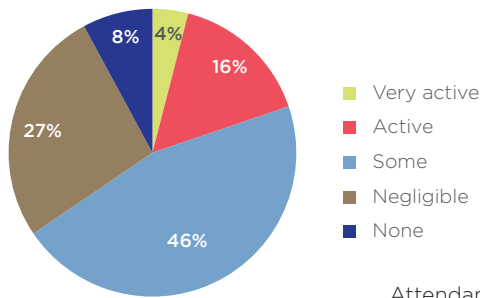
Are you member of any international society (incl. ISRM sister societies)?



How would you like to get ISRM related information?



## 07 How do you rate your level of engagement with ISRM?

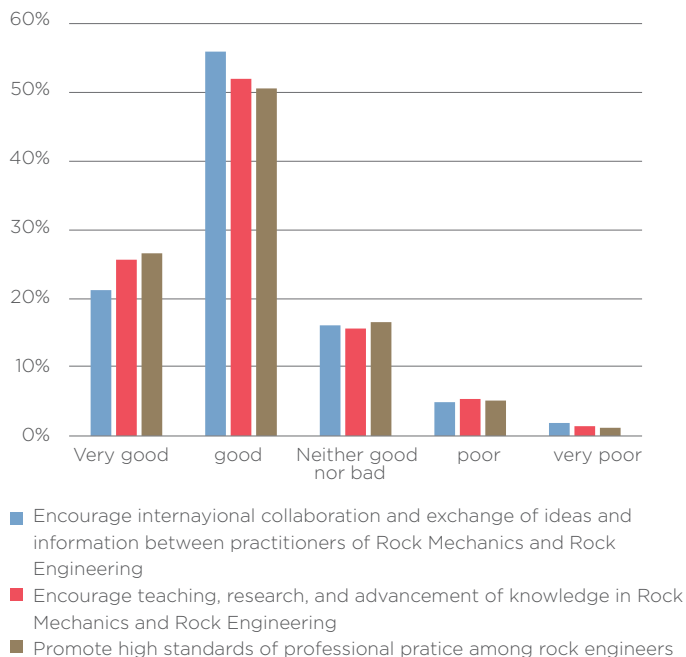


### What has been the nature of your engagements with ISRM?



- Majority of the respondents prefer e-newsletter for receiving ISRM related information
- Only 20% of the respondents considered themselves active in ISRM
- Attendance to ISRM sponsored conferences and regular access to ISRM website content and resources are the top engagement methods.

## ISRM RATING ACHIEVING ITS GOALS



### What other objectives should the society focus on?

Branding and recognition of the profession amongst young generations (teens and undergraduate students).

Promoting our profession to the general public and informing the general public about the relevance of Rock Mechanics and Rock Engineering to the World Economy and Industry

Engaging with general public to address sensitive environmental topics, which are relevant to sustainability of the planet: (e.g. CO2 underground sequestration, underground storage, fracking, rare earth mining, Oil exploration etc.)

Promoting practical Rock Mechanics applications for practicing Rock Engineering practitioners

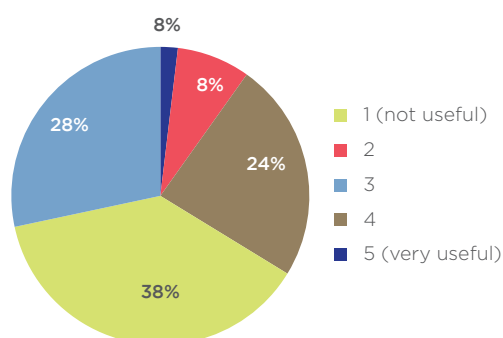
Branding and recognition of the profession and the society across all engineering disciplines

Branding and recognition of the ISRM to the Rock Engineering discipline across all continents.

- Overall, the respondents rated ISRM good to very good in achieving its goals
- Respondents were also positive with ISRM engaging in promoting the profession amongst public and next generations and activities related to sensitive environmental topics

## RATING OF ISRM SERVICES AND OFFERINGS

Are the services and the information provided by the ISRM useful for your work or study?



### Top 5 choices for additional benefits

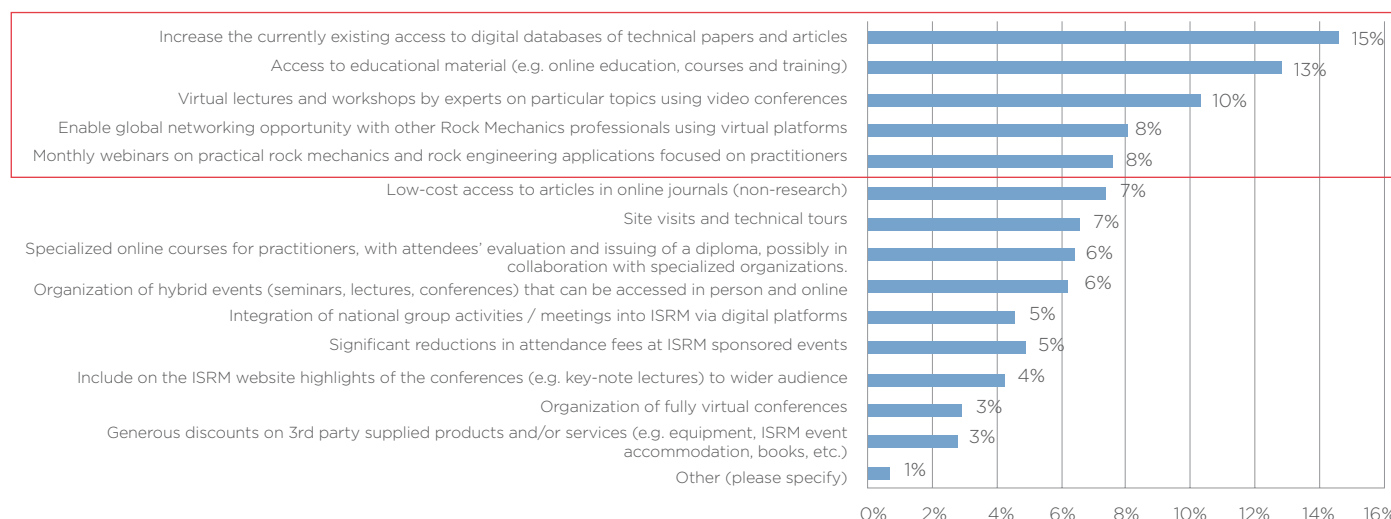
Increase the currently existing access to digital databases of technical papers and articles

Access to educational material (e.g. online education, courses and training)

Virtual lectures and workshops by experts on particular topics using video conferences

Enable global networking opportunity with other Rock Mechanics professional using virtual platforms

Monthly webinars on practical rock mechanics and rock engineering application focused on practitioners



- Over 60% of the respondents' rates ISRM offerings useful to very useful.
- Majority of the respondents also asked for increased access to digital database, additional educational materials, virtual events such as webinars, online lectures, and workshops.



## 07 RESPONSES TO OPEN QUESTIONS

Top three most important open questions in Rock Mechanics and Rock Engineering still to be answered?

- Deep rock mechanics
- Environmental protection
- Numerical modelling
- Induced seismicity
- Characterization and constitutive models
- Hazards and disaster prevention

What changes would you like to see implemented that would increase your satisfaction with your membership in the ISRM

- Easier (free) access to material, ie suggested methods
- Collaborative events, ie industry collaboration
- Greater dissemination of information, timely correspondence

What can the ISRM do to improve/boost the engagement of young engineers and researchers with the society?

- Inexpensive conferences and workshops, sponsored attendances
- Better online presence
- Free online events and specialized courses

Name the newest innovation that you regularly use in your field of work?

- Photogrammetry
- Numerical simulation
- Monitoring: insar, lidar, drones, laser scanning
- Artificial intelligence, machine learning, and virtual reality

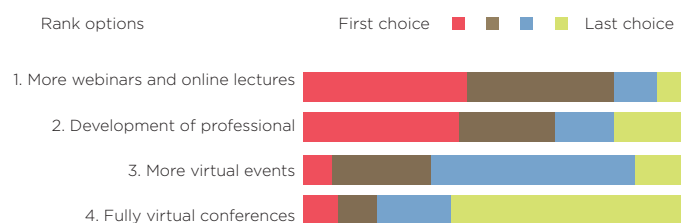
Name any new technology/innovation in your field of work that you would like to hear more about in ISRM events?

- Numerical modelling and analyses
- Monitoring techniques
- Artificial intelligence

How should the ISRM respond to possible long-term restrictions of international travel?

- Respondents would like ISRM to maintain online activities such as virtual conferences and online meetings post pandemic.
- Webinars and online lectures are more preferred than fully virtual conferences.

Which aspect of use of digital technologies would you like to see more used in ISRM?



Desired general topics for expert lectures of courses to be given in online ISRM courses or in ISRM Lecture Tours

- Slope stability
- Numerical modelling
- Induced seismicity 🚧

## FORTHCOMING ISRM SPONSORED CONFERENCES

### 2023

24-26	May	NROCK2023: The IV Nordic Symposium on Rock Mechanics and Rock Engineering Reykjavik, Iceland
7-10	June	3rd JTC1 Workshop: Impact of global changes on landslide risk Oslo, Norway
11-13	September	10th Nordic Grouting Symposium Stockholm, Sweden
9-14	October	15th ISRM International Congress on Rock Mechanics Salzburg, Austria
22-24	November	1st Chilean Congress on Rock Mechanics Santiago, Chile
2-7	December	1st SLRMES Conference: Rock Mechanics for Infrastructure and Geo-Resources Development Colombo, Sri Lanka

### 2024

15-19	July	Eurock 2024: New Challenges in Rock Mechanics and Rock Engineering - an ISRM Regional Symposium Alicante, Spain
24-28	September	ARMS13 - 13th Asian Rock Mechanics Symposium: Advances in Rock Mechanics - Infrastructure Development - an ISRM Regional Symposium New Dehli, India

### 2025

-	June	Eurock 2025: Expanding the underground space. Future development of the sub-surface - an ISRM Regional Symposium Alicante, Spain
17-23	September	16th ISRM International Congress on Rock Mechanics Seoul, Korea

The ISRM holds International Congresses on Rock Mechanics and Rock Engineering, at four year intervals, on themes of general interest to the majority of the membership, and sponsors a co-ordinated program of International Symposia, Regional Symposia and Specialized Conferences organised by National Groups of the Society.

The annual ISRM International Symposium is chosen from the ISRM Regional Symposia that take place in that year and is the venue for the annual meetings of the Council, Board, and Commissions of the Society. ISRM Specialized Conferences are events of a smaller nature, usually focused on a specific theme.

National Groups seeking to host an ISRM Regional Symposium or Specialized Conference shall submit a written proposal to the Secretariat, at least one, but preferably two to three years before the date of the event. Their organization is ruled by By-law No. 5, and application forms are included in specific Guidelines prepared by the Board, and available on the ISRM website (<https://www.isrm.net/conferencias/submit.php?show=conf>). Since 2018 no financial contribution to the ISRM is due from ISRM Specialized Conferences.

Proceedings of ISRM conferences are stored in the ISRM digital library available in the OnePetro platform ([onepetro.org](https://onepetro.org)).

## 09 REPORTS OF ISRM CONFERENCES

### IX LARMS

Asunción, Paraguay

The 2022 ISRM International Symposium, IX Latin-American Rock Mechanics Symposium (LARMS2022), was held as a face-to-face event between 16 and 19 October 2022 in the Bourbon Hotel, Asunción, Paraguay. The Symposium was organized by the Paraguayan Geotechnical Society and chaired by José Pavón (ISRM Vice-President), co-chaired by Roberto Andrada (President of the Paraguayan Society of Geotechnics), Eda Quadros (ISRM Immediate Past President) was the Honorary Chairman of the event. It was a very nice conference that followed the previous one held in South America, back in 1994, in Chile, and after the pandemic issues.

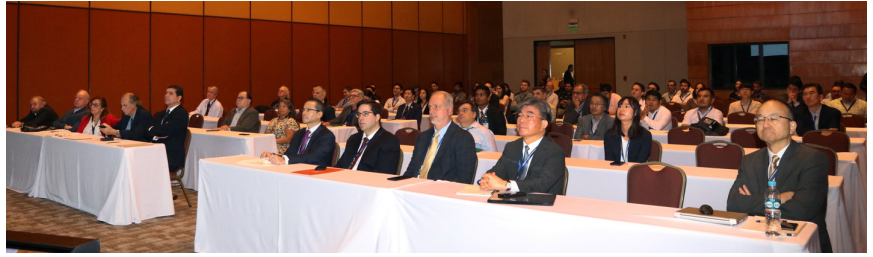
The symposium gathered 170 guests, co-authors and participants, coming from 31 countries from all continents. It started with an opening address by the ISRM President Prof. Reşat Ulusay, followed by the 2022 Rocha Medal presentation by Dr. Rhadika De Silva "Host rock pre-conditioning using non-explosive demolition agent for in-situ recovery applications" and the 2022 Franklin Lecture presentation by Dr Werner Bilfinger "Rock strength degradation in tunneling", which can be found in this News Journal issue.

The main theme of LARMS2022 was "Challenges in Rock Mechanics: Towards a Sustainable Development of Infrastructure". In the symposium, consisting of 10 technical sessions, a total of 71 papers were presented, divided into 10 technical sessions, and seven distinguished experts delivered the following seven keynote lectures:

- |   |
|---|
| Antonio Bobet (Spain USA): Frictional Discontinuities: The Mechanics and Imaging of Slip                              |
| Antonio Samaniego (Peru): Experiences and Lessons Learned in Geomechanical Studies for Narrow Vein Underground Mining |
| Doug Stead (Canada): Progress Toward Understanding Complex Rock Slope Failure Mechanisms                              |
| Ismet Canbulat (Australia): Time to Failure of Pillars – a Limited Equilibrium Analysis (virtual presentation)        |
| Nick Barton (Norway): Continuum or Discontinuum – that is the Question  |
| Norikazu Shimizu (Japan): Monitoring Ground Surface Displacements Using Satellite Technology (GPS/GNSS and SAR)       |
| Xia-Ting Feng (China): Rock mechanics for deep engineering (virtual presentation)                                     |

The Early Career Forum was a special part of this event that involved all the young attendees. In this forum, nine young speakers selected from eight ISRM member countries in Latin America (Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Mexico, Paraguay, and Peru) delivered presentations. It was an excellent opportunity for young researchers and professionals to interact with distinguished experts. The speakers

received their certificates from the ISRM President. The Rock Mechanics game between university students "RockBowl" had its seventh international edition during LARMS2022, involving eight teams from different countries (Bolivia, Brazil, Chile, Paraguay, Peru, and South Africa). This exciting competition created an atmosphere of friendship. The winning team came from South Africa.



Opening speeches by the ISRM President Reşat Ulusay, the conference Honorary Chairwoman Eda Freitas de Quadros, and conference Chariman José Pavón



Rocha Medal presentation





Winners of the Best Paper Awards and colleagues

Before LARMS2022, the ISRM Board meeting, two courses, and ISRM Council meeting were also held in the same venue between 14-15 October and on 16 October 2022, respectively. Since the majority of the annual meetings of the ISRM Commissions were held online, only the meeting of Commission on Testing Methods was held physically on 16 October in Asunción.

At the Closing Ceremony, the Award for Best Papers (both for General and Youth Categories), and the Milton Kanji Award from the Paraguayan Geotechnical Society were delivered to the winners selected by the respective award committees.

During the Welcome Reception Cocktail and Banquet Gala Dinner, where the ISRM Awards are given as usual, the participants had an excellent opportunity to interact with each other and establish new relationships. During



the dinner, the new five ISRM Fellows were inducted honouring them with a wide acknowledgement from the rock mechanics and rock engineering society. The medals and certificates of the new Fellows were handed to them by the ISRM President. Since some new Fellows were not able to attend the symposium, the distinctions were given to colleagues who will deliver them. 🇵🇷

## EUROCK 2022

Helsinki, Finland

The EUROCK 2022 Symposium with the theme “Rock and Fracture Mechanics in Rock Engineering and Mining” took place in the Dipoli Conference Center in Espoo, Finland, on 12-15 September 2022. The conference was jointly organized by the Finnish National Group of ISRM (Kalliomekaniikkatoimikunta) and the Finnish Association

of Civil Engineers (RIL). The EUROCK symposia belong to ISRM regional symposium series organised annually except every fourth year when ISRM Congress takes place. The first EUROCK symposium was held in 1992, in Chester, United Kingdom. This was the second time the EUROCK Symposium was held in Finland, the first one was organized in 2001, in Espoo.



ISRM actively supported the symposium with the presence of Reşat Ulusay (ISRM President), Leandro Alejano (Vice President for Europe), Ömer Aydan (Vice President at Large) and Seokwon Jeon (ISRM President-Elect). The opening and closing speeches were given by the ISRM President and VP for Europe, respectively.



**09** The symposium had 312 registered participants from 36 countries covering most European countries but also USA, Canada, China, India, Japan, South Korea, Taiwan, Australia, Indonesia, United Arab Emirates, Kazakhstan, Israel, Brazil, and Venezuela.

EUROCK 2022 included 183 presentations of which 128 were oral presentations and 51 were poster presentations. Presentations were accepted from both scientific and from technical topics. Scientific topics allowed longer elaboration and were peer-reviewed by two reviewers. Technical topics expanded the scope of the symposium and allowed for a briefer written reporting. The presentations were delivered over two days in four parallel sessions. Each day began with two keynote speeches given by Sanna Mustonen, Caroline Darcel, Michael Di Giovinazzo, and John Harrison on geological disposal of nuclear waste, inputs of discrete fracture networks, practical rock engineering, and Eurocode 7, respectively.

The proceedings consist of 132 accepted scientific papers that were evaluated and reviewed with the ExOrdo management system under themes ranging from Field and laboratory investigations to Rock mass characterization to Modelling to Rock mass behaviour including Support, Drilling, Geological disposal of spent nuclear fuel, Geophysics and Education as well as Case studies.

A total of five awards were issued: best paper award to L. Jacobsson and M. Godio for their paper "Measuring the hydraulic transmissivity of a rock joint under varying normal load", two runner-up best papers to S. Morajev

et al. and Ö. Aydan, best paper by a student award to B. Powlay et al. for their paper "The effect of notches on breakdown pressure during Hydraulic Fracturing at various stress regimes" and a runner-up award was given to A. Kumar A. and Tiwari G.

On the day prior to the conference four short courses were arranged on current topics such as 2D/3D modelling of fracturing processes, photogrammetry for rock mass characterization, and modern rock engineering principles; a workshop on "Recent ISRM Suggested Methods and Future Prospects" was also organized by the ISRM Commission on Testing Methods. On the day after the Symposium four technical excursions were arranged to the Sulkavuori underground water purification facility and the Sandvik test mine in Tampere, the Underground Research Laboratory of Aalto University (URLA) and the VTT underground research tunnels, the Katri Vala underground heating and cooling plant and the Merihaka civil defence shelter.

The ISRM Commission on Testing Methods organized a workshop on "Recent ISRM Suggested Methods and Future Prospects" on 12 September 2022, before EUROCK2022. With the aid of nine presentations, the aim of the workshop was to provide a forum of discussion on the contents of some selected new and revised ISRM Suggested Methods, the procedures which can be future prospective Suggested Methods and the practical implementation, feedback analysis and paths for improvement of the ISRM Suggested Methods. The workshop was chaired by the Commission President Resat Ulusay and was attended by 41 participants from 17 countries. All presentations were recorded in video

and are available in the ISRM website (<https://isrm.net/page/show/1652>). ▀



Participants in the ISRM Commission on Testing Methods Workshop



Visit to the Sulkavuori wastewater treatment plant



Best paper award



## ARMS12

Hanoi, Vietnam

Under the ISRM sponsorship, the 12th Asian Rock Mechanics Symposium ARMS12 was jointly organized by Vietnamese Society for Rock Mechanics (VSRM), Petro Vietnam University (PVU) and ISRM, and co-supported by the Vietnam Institute of Geological Sciences. It was held between 23 and 24 November at the Army Hotel, located in the imperial citadel of Thang Long (world's heritage), in Hanoi, Vietnam. The symposium was supported by six companies. ISRM also actively supported the symposium with the presence of Reşat Ulusay (ISRM President), Suseno Kramadibrata (ISRM Vice President for Asia) and Seokwon Jeon (ISRM President-Elect).

The symposium theme was "Rock Mechanics and Engineering - Contemporary Issues". About 100 participants from 15 countries located in Asia, Europe, North America and Australia attended the event. A total of 66 abstracts were received and 35 papers were presented in the symposium and published in the hard cover symposium proceedings that were distributed to participants during the event. The opening ceremony of the Symposium was chaired by Reşat Ulusay, Suseno Kramadibrata and Prof. Do Nhu Trang (President of VSRM) and the opening speech was given by the ISRM President.

In this symposium, six parallel sessions on the topics of rock properties and testing methods, rock mechanics and engineering in mining, tunnel and underground construction, geohazards (landslides, debris flows) and rock slope stability, rock mechanics and engineering in drilling and rock properties-numerical simulations were held. In addition, five keynote lectures were delivered by Reşat Ulusay on Future trends in rock testing and characterization, Suseno Kramadibrata on Geomechanics risk management system in Indonesian mining, Seokwon Jeon on Advances on rock excavation technology, Manchao He on Material innovation to engineering revolution, and Pinnaduwa H.S.W. Kulatilake on Stability and rock support assessment for an underground mine.

After the closing session, chaired by the ISRM President and ISRM VP for Asia; the Asian Council Meeting was held with the participation of the presidents and/or representatives of the national groups from Asia and chaired by Suseno Kramadibrata and then a city tour in Hanoi city was organized for the participants. 🇻🇳



ARMS12 opening session



ISRM President opening speech



Group photo

## 09 AUSROCK 2022

Melbourne, Australia

The Conference had 354 registered delegates from 19 countries, including Brazil, Canada, Chile, China, Germany, India, Indonesia, Iran, Israel, Japan, Kazakhstan, New Zealand, Norway, Singapore, South Africa, Turkey, the United Kingdom, the United States and Australia. It is noted that this is a record number of all AusRock Conference Series.

There were over 80 papers presented in parallel sessions during the conference. The session topics were ground control and support, dynamic events and managing large deformations, geotechnical instrumentation and monitoring, data management, laboratory experimentation, planetary rock mechanics, slope stability, mine design – geotechnical considerations, and numerical modelling.

The AusIMM President Dave Clark and President-Elect Nicole Brook, and ISRM VP At Large Prof Ömer Aydan also attended the Conference. İsmet Canbulat and Serkan Saydam from the University of New South Wales, Australia co-chaired the Conference.

The Conference opened by İsmet Canbulat welcoming the delegates. The AusIMM CEO Stephen Durkin also welcomed the delegates on behalf of the AusIMM. Reşat Ulusay, the President of the ISRM, officially opened the Conference with a video message. Serkan Saydam then introduced the first keynote speaker. Keynote speakers and respective talk titles are listed below.



İsmet Canbulat and Serkan Saydam, AusRock 2022 Co-Chairs

Rigoberto Rimmelin from the Practice Lead Global Geotechnical and Resource Centre of Excellence of BHPH: "Slope performance monitoring - Predictive tools to enable business continuity"

Rae O'Brien, Executive General Manager of Mining Excellence of Centennial: "Resources today, resources tomorrow"

Bruce Hebblewhite from UNSW: "Mining geomechanics – A retrospective look toward the future"

Robert Anderson from NASA's Jet Propulsion Laboratory: "Characterizing the geomechanical properties of planetary objects"

Charlie Li from the Norwegian University of Science and Technology: "Evolution of ground support and issues in the current rockburst support systems"

Alison McQuillan, Director of Rocscience Australia: "Does a FOS of 1.2 mean your slope will be stable?"

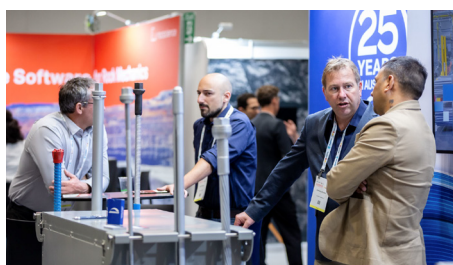




The panel discussion was organised before the closing session. The panel topic was “Future of Ground Engineering” and was moderated by Murat Karakus from the University of Adelaide. The panellists were Sarah Webster, Diana Carroll, Patrycja Sheffield and Joung Oh.



The AusRock 2022 Conference had two awards. The Best Paper Presentation Award was won by Matthew Woods from Newcrest Mining Ltd. Matthews paper titled “Measuring the influence of a sub-level cave on open stoping at Telfer”. The Conference also had the Best Early Career Paper Presentation award, which was won by Dr Honghao Chen from UNSW. His paper titled “Study of prevention methods for stress corrosion cracking in underground coal mines”.



## TUNIROCK 2022

Hammamet, Tunisia

The Second International Conference on “Advances in Rock Mechanics” TuniRock 2022, an ISRM Specialized Conference, was held in the very nice city of Hammamet, Tunisia, from 25 to 27 March. This is the Second International Conference organized by the Tunisian Society for Rock Mechanics (<http://www.atmr.tn/>) since its creation in 2012 and affiliation within ISRM as a National Group in 2013. In total, 28 papers were included in the TuniRock 2022 proceedings coming from Cameroun, China, France, Lebanon, Madagascar, Russia, Tunisia and Turkey. Papers dealt with rock mechanics and rock engineering research and applications. Mining,

Civil and Petroleum Engineering industries were also included. The main topics of the conference were Site Investigation Technology, Laboratory and in-Situ Testing, Rock Mechanics in Civil, Mining and Petroleum industries, Analytical and Numerical Modeling of Rock Mechanics Problems and finally, Risks and Hazards.

Reginald Hammah, Director RocScience Africa, delivered one Short one-day courses on “Fundamentals of Rock Slope Stability Analysis using Numerical Methods”. In total, 17 engineers and PhD students from administration, phosphates national company, university and consulting firms attended the course.

Rock Characterization and Testing and Future Trends: Highlighting the ISRM Suggested Methods, by Prof. Reşat Ulusay, Hacettepe University, Department of Geological Engineering; Ankara (Turkey)

Advanced Techniques for deep hard rock geothermal drilling, by Prof. Hédi Sellami, Mines Paris – PSL (France)

Stress, Structures and Deformations: The case of the occidental Mediterranean Sea and Surrounding Area, by Prof. Farhat Rekhiss, National Engineering School at Sfax (Tunisia)



**09** Moreover, three Keynote lectures were delivered during the TuniRock 2022 Conference:

A Best Paper award was delivered to Hajer Bannour on “Waste Disposal Facility on Limestone Deposit: case of study and how to reinforce it for Environmental Considerations?”.

The Tunisian Society for Rock Mechanics is grateful to the organizing and scientific committees as well as to speakers and keynote lecturers for taking time to share their knowledge within this major event. Thanks are also due to the President of ISRM, Reşat Ulusay and to the ISRM Secretary General Luis Lamas for their support. 🇹🇳



TuniRock 2022 group photo



Best Paper Award to Hajer Bannour.

## 5th SYMPOSIUM OF THE MACEDONIAN ASSOCIATION OF GEOTECHNICS

Ohrid, Macedonia

The first ISRM event fully to be realized in-situ after the one in Ljubljana in January 2020 was again in the Balkans. After several postponements due to the pandemic in the past two years, the Fifth Symposium of the Macedonian Association for Geotechnics (MAG) has ultimately took place between 23 and 25 June, in the Metropol Resort on the shore of the Ohrid Lake, one of the oldest and deepest European tectonic lakes, with numerous sites to explore, not just from a geotechnical point of view, since the city of Ohrid and its region are UNESCO's World Natural and Cultural Heritage.

From the very beginning of its planning (already in 2019), it was supported by the ISRM, so it took the form of the ISRM Specialized Conference, entitled “Engineering problems in soft rocks”. At the same time, it was the Second Conference of the regional geotechnical societies (Bosnia and Herzegovina, Croatia, Macedonia, Serbia and Slovenia) and was promoted by the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE). As such, it was recognized as an excellent opportunity to get acquainted with the activities of a solid number of associations, and also among the sister societies, so the presidents of

ISRM, Reşat Ulusay, and of ISSMGE, the recently elected Marc Ballouz, participated and, besides delivering opening speeches and keynote lectures, practically established their first contact. On the sidelines of the symposium, they met also with high officials of other societies as well, such as of Bulgaria, Albania, Hungary, Poland, Kazakhstan, which representatives were also present in Ohrid.

The past pandemic conditions led to a strong interest in participating. Thus, 94 papers were published in the proceedings (also available online), including one introductory, four keynote and six invited lectures by Milorad Jovanovski; Marc Ballouz, Nick Barton, Heinz Brandl, Resat Ulusay, Anna Maria Ferrero, Radomir Folic, Vojkan Jovicic, Ahmet Saglam, Ivan Vrkljan and Askar Zhussupbekov. 220 guests, co-authors and participants came from 30 countries from all of the continents. The papers were presented, either in one of the nine oral sessions, or in a poster session, followed by vivid discussions in a friendly atmosphere.

The ambient of the conference hall was enriched with booths of several domestic, regional and international companies, who, together with the sponsors, generously supported the organizers in their plans to have an attractive event. The cultural program was based on music as there were traditional songs at the Opening ceremony, while folklore dance and music was scheduled for the initial warming up of the participants





at the Conference dinner, after which – as could be guessed – rock music was played and followed by many, not necessarily young, participants. The conference program also included a boat trip along Ohrid Lake, with guided tour to Ohrid and sightseeing of one of the several settlements over wooden pile structure built above the lake about 3000 years ago.

This event also gave opportunity to deliver plaques for Honorary members of MAG to Resat Ulusay, Ivan Vrkljan and Radomir Folic. Later, Resat Ulusay, and two ISRM Past Vice Presidents, Ivan Vrkljan and Norikazu Shimizu, had a meeting with the Dean of the Faculty of Civil Engineering in Skopje.

All these numbers and realization encourage the hosts to apply for organizing events of a higher category. But what made all the guests especially happy is the new dimension of the symposium. Namely, as a special benefit from it, the opportunities that were served to the young colleagues should be pointed out: several companies, institutions and firms offered financial and material support for the preparation of diploma theses, seminar works and master theses, and covering registration fees for participation at international conferences. It was an additional value and motivating for further gatherings, especially after the very complex period which – we believe – we have left back in the history, as “there is nothing stronger on Earth than the rock; only – the human being”.



ISSMGE and ISRM Presidents





## 09 ROCODYN-4

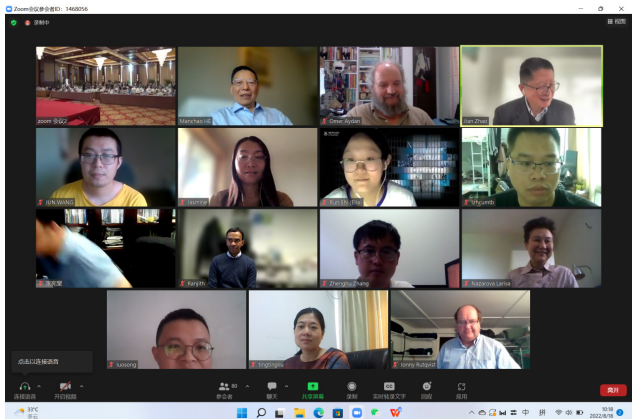
Xuzhou, China

The Fourth International Conference on Rock Dynamics and Applications (RocDyn-4), a specialized symposium of the International Society for Rock Mechanics and Rock Engineering (ISRM), was held on 17-19 August 2022 in Xuzhou China. The conference was organized by China University of Mining and Technology in Xuzhou and Southeast University in Nanjing, in association with ISRM Commission on Rock Dynamics. It was



The conference received over 200 abstracts and finally accepted 152 papers from more than 20 countries. The topics covered range from theories, testing and modelling to engineering, reflecting the progress and the prospect of rock dynamics as suggested by the title of the conference.

RocDyn-4 attracted more than 300 participants, with a hybrid on-site and on-line attendance format. The program included 9 keynote lectures, 7 Young Scholars Plenary Presentations, and 66 presentations in four



RocDyn-4 international conference on-site venue and some of the more than 100 online delegates

supported by Nanyang Technological University, Chinese Society for Rock Mechanics and Engineering (CSRME), State Key Laboratory for Geomechanics and Deep Underground Engineering, Yunlong Lake Laboratory of Deep Underground Science and Engineering, and an International Advisory Committee overseeing the RocDyn conference series.

The main theme of RocDyn-4 is "Rock Dynamics: Progress and Prospect", with the aim to take stock of the significant progress that rock dynamics has made since the formation of the ISRM Commission on Rock Dynamics in 2008, examine new research areas and applications, and look to the future of rock dynamics.

parallel sessions, namely, experimental testing and techniques, analysis and theoretical development, numerical modelling and methods, and rock engineering applications. The 9 keynote speakers were: Ömer Aydan on Earthquakes, Manchao He on Rockburst support, Jonny Rutqvist on fault activation and seismicity, Yulong Li on electromagnetic Hopkinson bar, Alexander Spathis on blasting, Larisa Nazarova on mining-induced seismicity, Gaofeng Zhao on rock dynamic modelling, Petr Konicek on destress blasting, and Zhanguo Ma on longwall mining support. For the first time, RocDyn-4 featured a Young Scholars Plenary Session (YSPS), with the speakers selected based on submitted papers and recommendations by the Scientific Committee. Significantly, most of the 66 oral presentations were made by students and young researchers and engineers. At the end of the conference, a short visit to the mountain in-situ experiment base of Yunlong Lake Laboratory was scheduled for all the on-site delegates.



Awards for the YSPS winners handed by Jianchun Li (left) and Yingxin Zhou (right)



Visit to the mountain in-situ Yunlong Lake Laboratory in Xuzhou

## 9th BRAZILIAN ROCK MECHANICS SYMPOSIUM

Campinas, Brazil

The 9th edition of the Brazilian Rock Mechanics Symposium (IX SBMR) was held in August 23-26th 2022 in the city of Campinas, São Paulo, Brazil. The central theme of the event was “Innovation and Technology in Rock Engineering”.

This event represents the most important Brazilian meeting for the presentation and discussion of scientific and technological research, projects and works in Rock Mechanics, and occurs in parallel with the 20th Brazilian Congress of Soil Mechanics and Geotechnical Engineering, 4th Brazilian Symposium of Young Geotechnical Engineers and the 6th South American Conference of Young Geotechnical Engineers and 11th Luso-Brazilian Congress of Geotechnics.



The main technical topics of this edition of IX SBMR were:

- Field and laboratory investigations in rock mechanics
- Foundations, excavations, and slopes in rocks
- Rock mechanics for mining
- Rock mechanics for tunnels
- Rock mechanics for petroleum geomechanics
- New technologies in rock mechanics
- Soft rock mechanics
- Rock mechanics applied to dams
- Rock as a building material

The IX SBMR featured two short courses in its programming. The former president of the Brazilian Rock Mechanics Committee (CBMR), Lineu Ayres da Silva will teach the course “Rock Blasting by Explosives in Urban and Underwater Areas”. The course “Fundamental Aspects to the Study of Rock Mechanics”, to be taught by Carlos Emmanuel Lautenschläger (CBMR Vice-President) will be aimed at students and young professionals.



As a tradition of CBMR in its most important national event, a RockBowl competition for university students took place during SBMR 2022. This 5th national edition of Rockbowl was again sponsored by Geobrug.

The event took place at Expo Dom Pedro, privileged location in the city of Campinas, which is ranked as the tenth wealthiest city in Brazil and is the main economic and cultural driver within the region, being remarkable for its life quality indicators and growth potential.

This will be the first edition of SBMR after the International Congress of Rock Mechanics and Rock Engineering (ISRM 2019), held in Foz do Iguaçu. It was an excellent opportunity to discuss the state of knowledge in rock engineering considering the latest international experiences. 🇧🇷



## 09 COUFRAC 2022

Berkeley, USA

The 3rd International Conference on Coupled Processes in Fractured Geological Media: Observation, Modeling, and Application (CouFrac) took place at Berkeley Lab and online everywhere else on November 14-16. Berkeley Lab Research Scientist Mengsu Hu led the conference along with Berkeley Lab Senior Scientists Carl Steefel and Jonny Rutqvist to explore the exciting new advances in all areas of coupled processes associated with fractured geological media.

The conference was sponsored by both American Rock Mechanics Association (ARMA) and International Society for Rock Mechanics and Rock Engineering (ISRM). It was the result of 11 months of effort and preparation by these Berkeley Lab co-chairs, who were joined in their efforts by Ki-Bok Min (Seoul National University), Antonio Pio Rinaldi (ETH Zürich), Pengzhi Pan (Institute of Rock and Soil Mechanics, CAS), Hideaki Yasuhara (Ehime University), and 43 organizing committee members and session conveners. The conference was a great success, with 256 participants (including 150 onsite and 106 online) from 32 countries and regions.



Attendees of the CouFrac 2022 Conference.

The conference included a discussion of “Carbon Neutrality” with panel members Derek Elsworth, Dongxiao Zhang, Maurice Dusseault, Hajime Yamamoto, Ranjith Gamage. Also included were six keynote lectures given by Chin-Fu Tsang, Wenlu Zhu, Janos Urai, Mark Zoback, Patrick Selvadurai, and Jishan Liu, and seven Distinguished Invited Lectures given by Christopher Spiers, David Nolte, Hari Viswanathan, Hongkyu Yoon, Yuxing Ben, Gregory Beroza and Nantheera Anantrasirichai. Peter Kang from University of Minnesota gave the Chin-Fu Tsang Award Lecture, and Cyprien Soulaire, Anna Suzuki, Xuhai Tang, Sehyeok Park, Harrison Lisabeth, and Luke P. Frash gave Emerging Scientist Plenary Lectures. Berkeley Lab Affiliate Scientist Tim Kneafsey delivered a Distinguished Banquet Speech highlighting personal and professional experiences in investigating coupled processes.

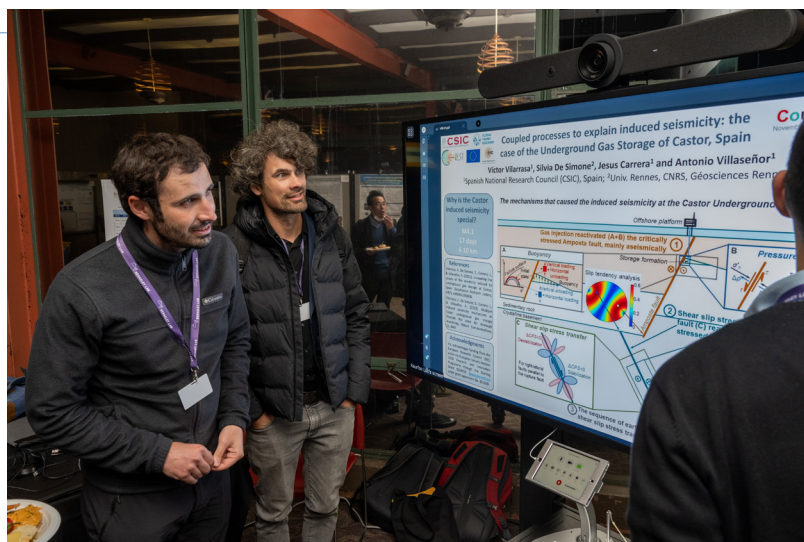
The conference included 24 technical sessions with 118 talks (including 7 invited lectures), 6 virtual poster sessions with 44 virtual posters, and an onsite poster session with 26 posters. The conference program covered a wide range of classic topics relevant to coupled processes in fractured media, including numerical modeling, lab tests, field tests, hydraulic fracturing, flow and transport, induced seismicity, geothermal energy, nuclear waste disposal, and carbon sequestration. In addition, several sessions new to CouFrac2022 were developed by the organizing committee members and session conveners, including machine learning, hydrogen storage, Earth’s critical zone, shearing of fractures, reactive transport, salt mechanics and science, and clay and shale.

The 2022 Chin-Fu Tsang Coupled Processes Award—named after Berkeley Lab Senior Scientist Emeritus Chin-Fu Tsang was given to Peter K. Kang of the

University of Minnesota who was selected from among 12 outstanding international nominees. The Chin-Fu Tsang Award, which will be given at all subsequent CouFrac conferences, was created to recognize outstanding contributions from early career geoscientists investigating thermal-hydrological-mechanical-chemical (THMC) coupling in fractured rock. 🇺🇸



Keynote lecture by Chin-Fu Tsang



CouFrac 2022 Virtual Poster Session moderated by Roman Makhnenko



# 10 ISRM TECHNICAL OVERSIGHT COMMITTEE 2022 ANNUAL REPORT

Laura J. Pyrak-Nolte, Chair, VP for North America

Leandro R. Alejano, Member, VP for Europe

Ömer Aydan, Member, VP at Large

## 1. INTRODUCTION

The ISRM has established technical commissions to study scientific and technical matters of interest to the Society. ISRM commissions cover different topics, so they are varied in terms of their aims, type of activities, membership and products. In recognition of the critical role of the ISRM commissions for the achievement of the ISRM goals of international collaboration, advancement of rock mechanics and the promotion of

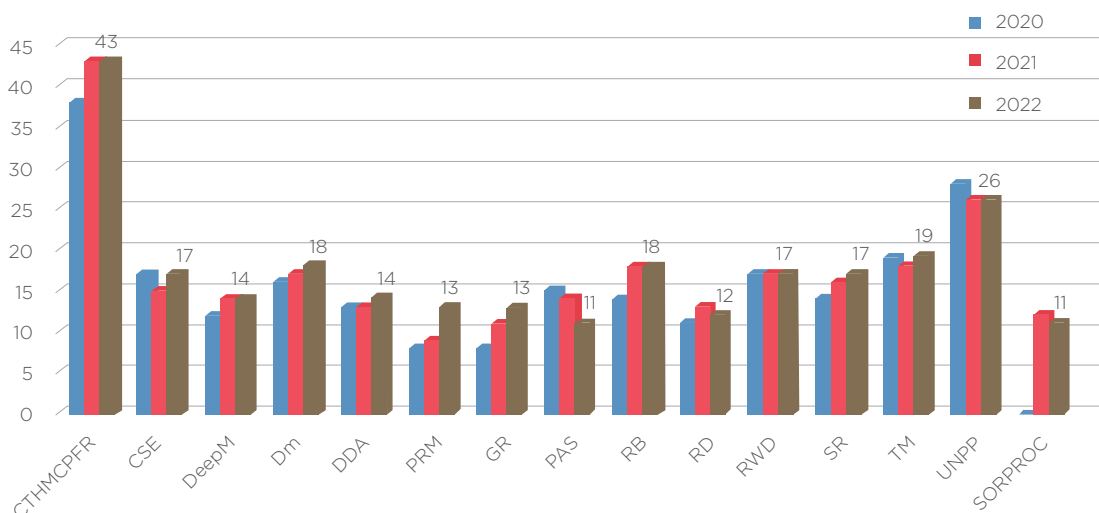
high standards, the ISRM Board created the Technical Oversight Committee (here in referred to as “the TOC”), to report on the performance and to act as oversight for the commissions. The TOC assesses commission performance based on commission-generated Annual Reports by the chair of each commission.

This report contains the TOC’s assessments of the commission for the 2021-2022 and planned activities for the next year.

**TABLE 1. ISRM TECHNICAL COMMISSIONS**

Commission Name	Year Established	Rating
1. Coupled Processes in Fractured Rock (CTHMCPR)	2018	Excellent
2. Crustal Stress & Earthquakes (CSE)	2011	Very Good
3. Deep Mining (DeepM)	2019	Very Good
4. Design Methodology (DM)	pre 2004	Very Good
5. Discontinuous Deformation Analysis (DDA)	2011	Excellent
6. Planetary Rock Mechanics (PRM)	2019	Good
7. Preservation of Ancient Sites (PAS)	pre 2012	Poor
8. Rockbursts (RB)	2019	Poor
9. Radioactive Waste (RW)	2010	Poor
10. Rock Dynamics (RD)	2007	Very Good
11. Rock Grouting (RG)	2019	Good
12. Soft Rock (SR)	2019	Poor
13. Sorptive Rock (SORPROC)	2021	Very Good
14. Testing Methods (TM)	~1970s	Excellent
15. Underground Nuclear Power Plants (UNPP)	2012	Good

**Commission Members by Commission**



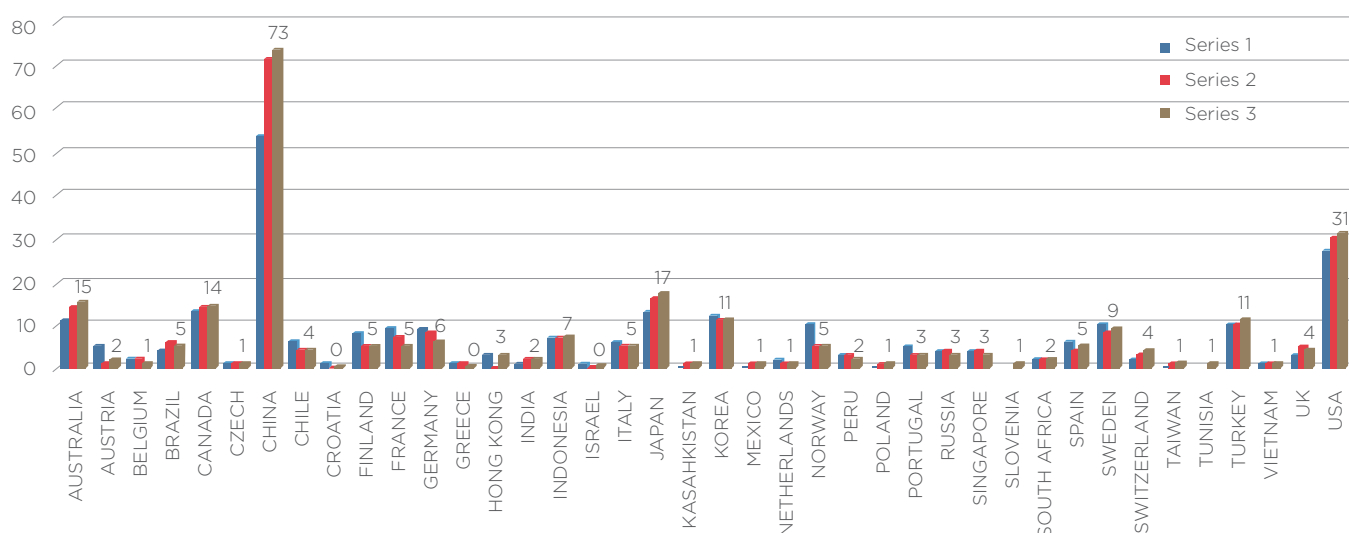
## 2. CURRENT TECHNICAL COMMISSIONS

There are 15 ISRM technical commissions (Table 1) with 266 commission members from 36 different national groups. Table 1 contains a list of current commissions, the year the commission was established and the rating of the performance of each commission.

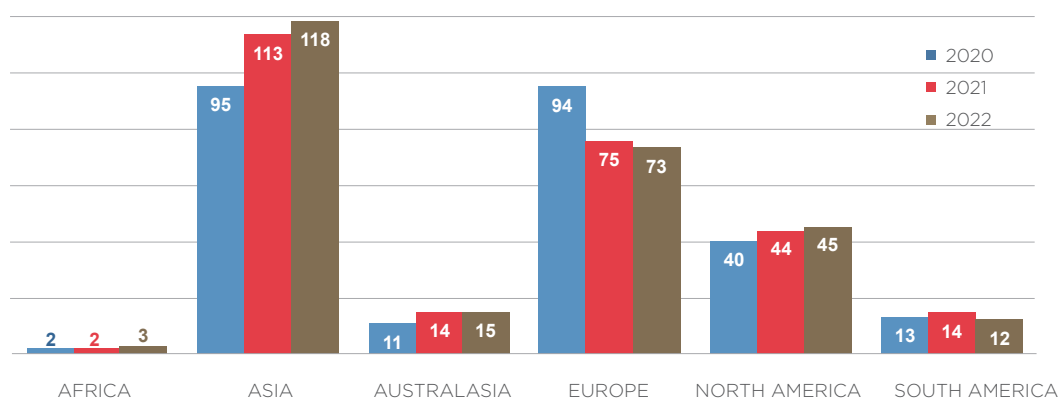
Commissions are typically composed of 12-15 members (Figure 1). The Commission on Coupled Processes in Fractured Rock (CTHMCPFR) has nearly 43 members because of their strong commitment to encouraging participation by early- and mid- career scientist and engineers.

The TOC reviewed the composition of the commissions to assess and encourage diversity in participation from different national groups (Figure 2). For 2021-2022, 36 national groups have members on a technical commission with China and the United States of America (USA) making the largest contributions to the commissions. If analyzed by region (Figure 3), Asia and Europe have the strongest participation in the commissions. However, participation from Europe has decreased 22% while members from Asia have increased by 24%.

Commission Members by Country



Commission Members by Region



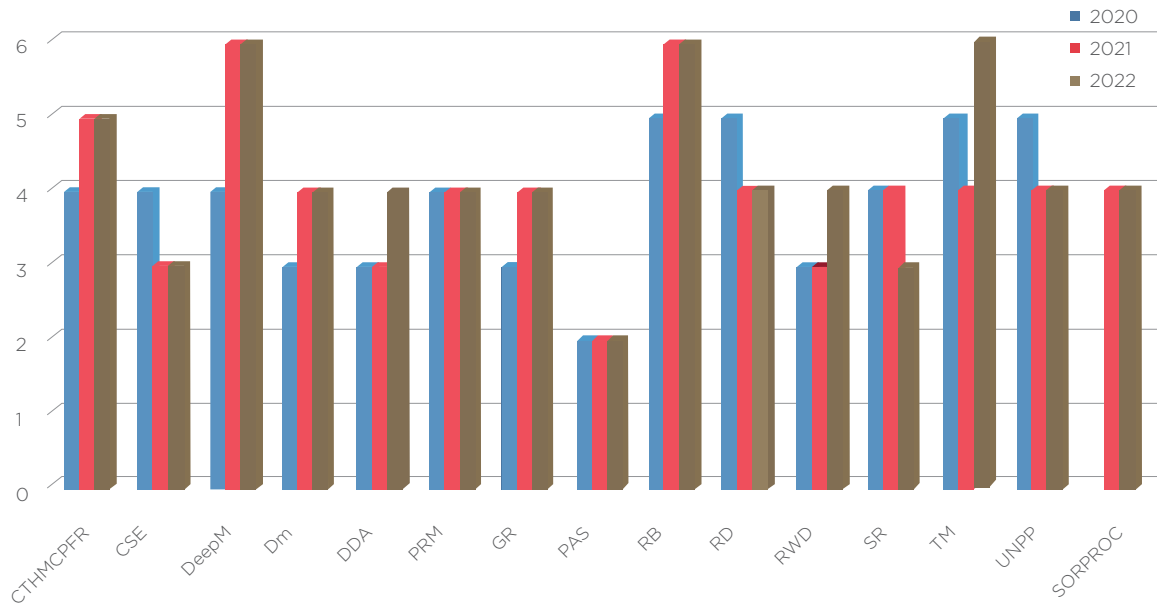


**10** The number of regions represented on each commission is shown in Figure 4 and the number of members from a particular region for each commission is shown in Figure 5. The commissions on Deep Mining (DeepM), Rock Burst (RB) and Test Methods have good representation with member from all six regions while Radioactive Waste (RWD) now has members from 4 regions.

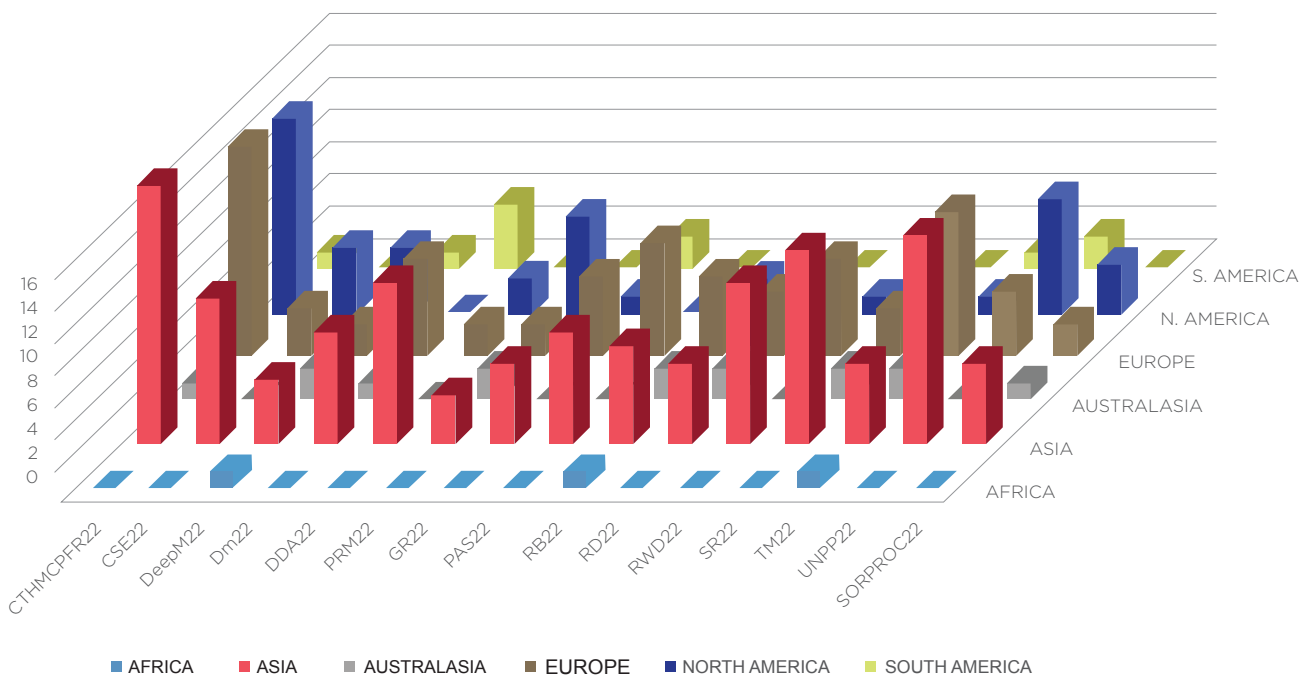
### 3. SUMMARY OF COMMISSION ACTIVITIES

Previous TOCs developed a standard template for the Annual report to provide awareness of a commission's activities, products, and progress during the year. The rating for each commission is based on the TOC's review of the annual reports.

Commission Regions per Commission



Commission Membership by Regions 2022



## 4. SUMMARY AND RECOMMENDATIONS

### 4.1 ISRM Commission Activity Summary

All 15 commissions produced an annual report describing the commission activities for 2021-2022 and planned activities for 2022-23.

Most of the commissions are performing at a high level or at a sufficient level with no major concerns. While several commissions continue to perform at a very high/high level of activity with no major concerns (e.g. Coupled Processes in Rock (CTTHMCPFR), Discontinuous Deformation Analysis (DDA), Rock Dynamics (RD) and Testing Methods (TM)), a few commissions have shown a decrease in productivity and performance (Preservation of Ancient Sites (PAS), Radioactive Waste (RWD) and Soft Rock (SR)). The relatively new commission on RockBurst (RB) has shown a decrease in productivity.

The TOC continues to monitor the diversity of the commissions. Diversity is used in the broadest sense and includes gender, ISRM region, area of study, academic-industry-national laboratories, academic heritage, etc. The TOC encourages all commissions to seek out interested members from Africa and South America to participate in the commissions and to encourage women to participate in commissions. Commissions that need to broaden regional diversity include Crustal Stresses and Earthquakes (CSE), Preservation of Ancient Sites (PAS) and Soft Rock (SR) because their membership is from < 3 regions. A concern are commissions dominated by members from a single country (Figure 6). A suggestion is that membership from a single country should be ~ 30% or below of the total number of members.

In 2021, the Commission on Preservation Ancient Sites (PAS) was advised to make significant changes in the operation and increase the productivity of the commission to avoid dissolution. This commission membership is not sufficiently diverse (different countries, academic versus industry, rock mechanics specialists, gender, etc.) and all publications have been in Chinese. The TOC recommends dissolution of the PAS commission.

The impact of the COVID-19 pandemic continues to decrease with many commissions meeting in person in addition to virtual meetings. The TOC strongly commends the commissions for finding virtual approaches to continue the activities and productivity of the commissions.

A good number of activities including conferences, meetings, workshops, courses, forums, publication of relevant journal special issues and suggested methods are planned by the Commissions for next year.

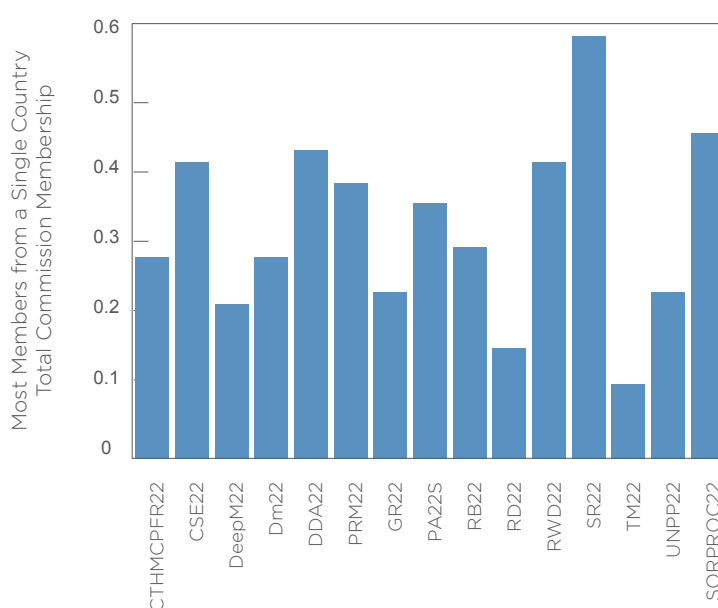


Fig 6. Fraction of members from a single country relative to members for a commission for 2022

## 10 4.2 Overview of ISRM Commission Activity Summary Publications

The commission on Underground Nuclear Power Plants (UNPP) published a book in October 2022. The Commission of Testing Methods (TM) will also publish a book when around 15 new Suggested Methods are published. The last book was published in 2015 (the Orange Book) and the new one is expected in one or two years. The TM commission has a suggested methods (SM) publication in preparation: Dynamic Shear Testing of Rock Discontinuities and Interface, and several new SM proposals: "Determining strength, deformation and toughness parameters of rock reinforcement tendons under an impulsive load- Method 1: Mass Freefall (MF) Method", "Scale Linear Rock Cutting Test", Quantitative Description of Discontinuities in Rock Masses", "In-Situ Determination of the Shear Strength of Discontinuities and Interfaces", "Direct Tensile Strength Test", "Triaxial Compression Testing of Shales and Mudstones", "Saturation of Rocks", "Determining the dynamic shear strength and mode II fracture toughness of rock materials using the Split Hopkinson Pressure Bar (SHPB)".

The Commission on Coupled Thermal-Hydro-Mechanical-Chemical Processes in Fractured Rock published four special issues of international journals that include Journal of Rock Mechanics and Geotechnical Engineering (19 papers), Rock Mechanics and Rock Engineering (10 papers), Computational Geosciences (11 papers), and Tunnelling and Underground Space Technology (13 papers), and were completed and published by October 2020. This Commission is planning a special issue in the international journal Geomechanics for Energy and the Environment in the spring of 2022.

### Conferences, Workshops, Short Courses

The Commission on Coupled Processes (CTHMCPFR) has organized a hybrid Conference "CouFrac-2022" at Lawrence Berkeley National Laboratory, Berkeley, California that will be held in November 2022

The Commission on DDA held the First Graduate Forum for Discontinuous Deformation Analysis (online) June 2022; the 16th International Conference on Analysis of Discontinuous Deformation (ICADD-16), Nov. 2022 in China; a short course of four-dimensional lattice spring model (4D-LSM) Aug. 2022, during RocDyn-4 in China. Organized: a session "Discontinuous deformation analysis in geotechnical engineering" for China Rock 2022, Organized: training course on discrete numerical simulation tool "NumericalBox3D" during China Rock Oct. 2022; and several online lectures.

The Commission on Testing Methods held the Workshop entitled "Recent ISRM Suggested Methods and Future Prospects" in Aalto University, Espoo, Helsinki, Finland on 12 September 2022, the day before the starting of the European ISRM Congress Eurock 2022. This workshop provided a forum of discussion with the aid of presentations on the content of some selected new and revised ISRM Suggested Methods. The idea was also to serve as a platform to initiate and enhance further interests on SMs among ISRM members. Reşat Ulusay, Chairman of the Commission and ISRM President, moderated this workshop. 41 persons from 17 countries attended the workshop, including 8 members of the Commission. Moreover, the workshop was video recorded and hung in the ISRM webpage.

15 of the 16 commissions have held Workshops or organized sessions at major conferences on their topic of interest.

In a 2021 virtual meeting of TOC with Commissions' chairmen, Commissions were encouraged to produce short courses and some guidelines were provided. A 5-part video course on ISRM website on Crustal Stress Assessment and its Application in Engineering and Earthquake Research was created by the CSE commission, and a 9-part video course "Rock Failure Behavior and Control in Deep Mining" (with 200-400 views) posted on Commission's YouTube channel by the DeepM commission.

### 4.3 Discontinued Commissions/Inactive Commissions 2020-2021

The commission on the Evolution of EuroCode 7 and Preservation of Ancient Sites has been dissolved by the President of the ISRM.

### 4.4 Activities of the ISRM TOC

In 2022, the TOC assessed all reports that were received from the 15 technical commissions and held a meeting of the TOC at EuroRock in Helsinki, Finland to discuss the commissions.

### 4.5 TOC Goals for 2022-2023

The TOC plans to hold a meeting at in 2022 with all available commission chairs to encourage their work, address questions, to facilitate collaboration among the commissions and to assess progress on video lectures and commission collaboration. 🚩

## ISRM EDUCATION FUND COMMITTEE 2022 ANNUAL REPORT

Qiang Yang | EFC Chair

### EDUCATION FUND COMMITTEE (EFC)

The objective of the ISRM Education Fund is to further the ISRM's mission, by enhancing education in Rock Mechanics and Rock Engineering. It will do this by planning, funding, coordinating and conducting educational activities for the benefit of the ISRM community. The ISRM Education Fund is managed by the ISRM Education Fund Committee. Qian Yang is the Chairman of EFC and the other EFC members for the term 2019-2023 are Manchao He, Seokwon Jeon, José Pavón, Ismet Canbulat, and Luís Lamas.

The 7th Early Career Forum, chaired by José Pavón, was successfully included in the IX Latin American Rock Mechanics Symposium, in Asunción, Paraguay. On this occasion, nine participants were nominated by ISRM National Groups from Latin America, including representatives from Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Mexico, Paraguay, and Peru. It was an exciting opportunity for those who are still starting their careers to share ideas and knowledge with those who have a great and successful experience in the field.



The nine young delegates attending the 7th Early Career Forum are below:

Juan Cruz Barría Argentina | Mechanical and microstructural behavior of cement-rock interface for CO<sub>2</sub> geological storage

Vladimir Ugarte Ontiveros Bolivia | Shales and slates of El Sillar, Bolivia: Description of degradation processes

Kimie Suzuki Morales Chile | Use of statistical techniques for improving rock mass characterization

María Elena Valencia Vera Chile | Machine learning in mining: Uses and techniques applied in geomechanics

Roy Ruiz Vásquez Costa Rica | Geotechnical design of temporary support for a drinking water transfer tunnel

Hazel Gonzalez Mexico | Modeling of the damage in the contour of tunnels caused by the use of blasting using the DEM

Nicolás Zabrodiec Paraguay | Evaluation of tip bearing capacity of bored piles embedded in the Vallemí-Cambajhopó limestone formation

Victor Vergara Peru | Geotechnical Design Strategies in Open Pit Mine with the Presence of Old Underground Excavations

### MANAGEMENT OF EDUCATION FUND

Qiang Yang has successfully raised a fund of 100 000 RMB (about \$15 450) to the EFC Beijing office. The total amount of \$15000 was used to support the 7th Early Career Forum.

### EARLY CAREER FORUM

The ECF is an ISRM Education Fund initiative that occurs during the ISRM Regional Symposiums. Its objective is to promote the participation of outstanding young researchers and/or practitioners in rock mechanics and rock engineering from the region in a technical session with a special format.

### SPECIAL EDUCATIONAL ACTIVITY IN AUSROCK2022

Two EFC Activities associated with AusRock 2022 were organized by Prof. Ismet Canbulat. A young professional focused webinar on Digitalisation and Integrated Visualisation was held on June 9, 2022, and a panel discussion on education, training, and professional development was arranged. ▀



## 12 ISRM YOUNG MEMBERS COMMITTEE 2022 ANNUAL REPORT

Sevda Dehkhoda, Chair  
Vojkan Jovicic  
Michael du Plessis

### INTRODUCTION

The goals of the ISRM Young Members' Committee (YMC) have been as follows:

- Attracting and engaging with young members of the society
- Providing platforms for networking and connection of young members
- Building opportunities for technical and professional learning and development
- Showcasing and celebrating the achievements of young members
- Attracting future generation into the discipline and
- Enhancing the recognition of the profession within the general public

In line with set objectives, the Committee's major activities for the year 2022 have been:

- Providing advisory role to the organizing committee of ISRM Young Members' Seminar Series
- Collaboration with ISRM Education Fund committee in organization of Early Career Forum
- Coordination of the selection committee of ISRM Young Rock Engineer award
- 2022 ISRM members' survey

### ISRM YOUNG MEMBERS SEMINAR SERIES

Since its establishment in November 2021, the ISRM Young Members' Seminar Series have provided platform for young members to collaborate and showcase the achievements of their peers. In year 2022, the organizing committee delivered 11 live seminars with 22 speakers from all over the world. The recordings of these presentations are available on ISRM Young Members YouTube channel @isrmyoungmemberschannel7287.

Young members interested in this event are encouraged to contact YMC and the organizing committee through ISRM.YM.Seminar@gmail.com. Criteria for the speakers are as below:

- be an ISRM member
- have a maximum age of 35 years, or of 40 years if a PhD degree was obtained in the previous 5 years;
- have worked in rock mechanics and rock engineering for a period no longer than ten years.

The ISRM Young Members' Seminar Series has been managed by an Organizing Committee, composed of young ISRM members from all ISRM regions. The main duties of the Organizing Committee are to select the topics of the seminars, to approve the speakers and to plan, manage, and promote the seminars. 🇳🇵

The screenshot displays the YouTube channel page for 'ISRM Young Members channel', which has 199 subscribers. The page is organized into a grid of video uploads. The left sidebar shows the YouTube navigation menu with options like Home, Explore, Shorts, Subscriptions, Library, and History. The main content area features a grid of video thumbnails, each with a title, duration, and view count. The videos are categorized under 'Uploads' and are sorted by date. The titles of the videos include 'ISRM YM Monthly Seminars - September 2022', 'ISRM YM Monthly Seminars - August 2022', 'ISRM YM Monthly Seminars - July 2022', 'ISRM Young Member's Monthly Seminar Series - 2...', 'ISRM Young Member's Monthly Seminar Series - 2...', 'ISRM Young Member's Monthly Seminar Series - 2...', 'ISRM Young Member's Monthly Seminar Series - 3...', 'ISRM Young Member's Monthly Seminar Series - 2...', and 'ISRM Young Member's Monthly Seminar Series - 2...'. The view counts for these videos range from 104 to 525 views.

## LIST OF 2022 ISRM YOUNG MEMBERS SEMINAR SERIES

26-Jan	Modelling the time dependent behaviour of fractured zone around underground storage structure in argillites, by Sophie Jung (France)
	Challenges in the Lyon-Turin base tunnel project, by Alessandra Insana (Italy)
23-Feb	Development of coupled thermal-hydraulic-mechanical-chemical (THMC) models for predicting rock permeability change, by Sho Ogata (Japan)
	Comprehensive in-situ stress estimation for a fractured geothermal reservoir from drilling, hydraulic stimulations, and induced seismicity, by Sehyeok Park (South Korea)
30-Mar	Numerical modelling of rock masses in block cave mining, by Kimie Susuki (Chile)
	Strategy and tactics for burst-prone conditions in a deep underground mine, by Alexander Ramos (Peru)
28-Apr	Experimental analysis of burst type extreme rock failures and rock fracture under high-stress conditions, by Selahattin Akdag (Australia)
	Coseismic rock slope failure mechanisms - insights from landslides triggered by the 2016 Mw 7.8 Kaikōura earthquake, by Corine Singsein (New Zealand)
27-May	Directional and 3D-Confinement-Dependent Fracturing, Strength and Dilation Mobilization in Brittle Rocks, by Masoud Rahjoo (Canada)
	Stochastic Discrete Element Modelling for Pillar Strength Determination: a First Step in a Risk-Based Pillar Design Approach, by Juan José Monsalve (USA)
28-Jun	Extended Finite Element Procedures for the Analysis of Reinforced Dual-Permeable Rock Media, by Yashwanth Kumar Gujjala (South Korea)
	A probabilistic-based approach to rock slope stability analysis in open-pit mine using numerical modelling, by Lewis Mathe (South Africa)
29-Jul	Innovation of giant NPR cable and its advantages in critical slip warning for landslide disaster, by Chun Zhu (China)
	Reconciliation between laboratory and in situ measurement of elastic stiffness for Opalinus clay, by Lang Liu (Canada)
26-Aug	4D computed tomography of granular force chains, by Wei Li (USA)
	Coupled Thermo-Hydro-Mechanical Modelling of Radioactive Waste Disposal in Rock Salt, by Hafssa Tounsi (USA)
30-Sep	Introducing CSM2020 –Discrete Event Simulation Model for Predicting TBM Utilization, by Anuradha Khetwal (USA)
	Deformation analysis and monitoring in underground constructions: automatic systems to measure convergence and pre-convergence effects, by Alessandro Valletta (Italy)
27-Oct	Differentiating cratering mechanisms behind rock blasting based on geomechanical characterization, by Jonathan Aubertin (Canada)
	Application of recent fracture mechanics criteria to notched rock fracture analyses, by Jon Justo (Spain)
28-Nov	Structural Mechanisms contributing to large-scale hanging wall instabilities on the UG2 Reef Horizon, by Alida Hartzenberg (South Africa).

## 12 Seminar Series Organizing Committee



**Romy Ridl**  
University of Canterbury  
& KiwiRail  
New Zealand



**Lina Maria G. Carrillo**  
École des Ponts  
ParisTech  
France



**Ryota Hashimoto**  
Hiroshima University  
Japan  
(currently in USA)



**Daisuke Fukuda**  
Hokkaido University  
Japan



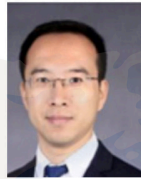
**Kimie Suzuki**  
Chile University  
Chile



**Ignacio Pérez-Rey**  
University of CEDEZ  
Spain



**Federico Vagnon**  
University of Torino  
Italy



**Zhihong Zhao**  
Tsinghua University  
China



**Jennifer Day**  
Queen's University  
Canada



**yudhidya wicaksana**  
Institute Teknologi  
Bandung Indonesia

### ISRM YOUNG ROCK ENGINEER AWARD

In October 2020, the ISRM Board instituted the ISRM Young Rock Engineer Award to acknowledge excellence in the field of rock engineering by ISRM members who are in early stages of their career.

At the 9th Latin American Rock Mechanics and 2022 International ISRM Symposium the second Young Rock Engineer Award was conferred to Dr Yota Togashi, nominated by the NG Japan. Dr Togashi is currently an Assistant Professor at the Rock Mechanics Laboratory of the Graduate School of Science and Engineering at Saitama University, Japan.

The nominations for the 2023 award will open in March 2023, six months ahead of 2023 ISRM Congress. Nominations for the award shall be by the nominee's National Group, or by some other person or organization acquainted with the nominee's work.

The eligibility criteria for the award are as below:

- be an ISRM individual member;
- have a maximum age of 40 years;
- have worked in rock engineering within the relevant industry for a period of about five to ten years.

### 2022 ISRM MEMBERS' SURVEY

The survey was released between March to April 2022 and distributed in 3 languages of English, Spanish, and Chinese to ISRM members and non-members. Overall, 737 people responded to the survey, 15% of which were under 35 years old. The members were asked what the ISRM can do to improve/boost the engagement of young engineers and researchers with the society, the responses included: inexpensive conferences, better online presence, free online events, and specialized courses. The survey results will be provided in a separate report. 📊



## 2022 REPORTS OF ISRM VICE-PRESIDENTS

### AFRICA

Michael du Plessis | Vice President for Africa

There are three recognised national groups (NG) of the ISRM within the African Region. These are the South African National Institute of Rock Engineering (SANIRE), the Tunisian Society for Rock Mechanics (TRSM) and the Zimbabwean National Institute of Rock Engineering (ZINIRE)

Botswana showed interest to establish a new national group. The process has, however, been delayed due to several of the interested parties driving the process moving between jobs or other areas. This remains a challenge in establishing national groups in many of the prominent countries in Africa. Due to the remoteness of operations or moving of key people (i.e. Zambia, Congo) the establishment of new national groups has been unsuccessful. Membership growth remain a focus of the ISRM. Areas of attention includes Zambia, Namibia, Ghana, Morocco, Mali, Tanzania, Nigeria, Egypt and the DRC. Currently, persons interested in being associated with the ISRM are joining through either SANIRE or TRSM. SANIRE being a very active NG attracts a lot of interest from international delegates and has various active members from various African countries and countries on other continents.

The following feedback was obtained from the three recognised national groups:

#### TRSM (Tunisian Society for Rock Mechanics)

Prof Essaieb Hamdi is the current president. The membership growth has remained steady over the past year.

Tunisia hosted the Second International Conference on "Advances in Rock Mechanics" (TuniRock 2022), an ISRM Specialized Conference which took place from 25-27 March 2022. A total of 28 papers were included in the proceedings. This included representation from Cameroon, China, France, Lebanon, Madagascar, Russia, Tunisia and Turkey.

The society is very active in initiating, arranging and hosting topical research topics. They arranged a series of webinars on data science applications in Rock Mechanics and Rock Engineering. They also hosted a webinar on machine learning in Nov 2022 and established an international working group on this topic.

#### ZINIRE (Zimbabwe)

Mr. Adias Mudzovaniswa was elected the president for the term 2022 – 2024. The membership has grown to 59 active members and 38 student members. The group activity was relatively low during and post COVID with limited meetings and only 1 technical visit conducted over the past year. They continue to promote the professional development of their members and the participation in ISRM activities and events.

#### SANIRE (South Africa)

Mrs Lizelle Prinsloo is the president for the terms 2021 – 2023. SANIRE currently has approximately 650 members with membership continuing to grow annually. The council arranged many technical events, workshops and social activities. This is further supported by the technical visits and technical evenings hosted by the 6 branches which ensures that members in various areas of the country remains engaged.

Some of the prominent events hosted over the past year included:

- National symposium which attracted more than 200 attendees,
- Rockbowl competition hosted to select the national team which participated and was awarded the overall winners at the LARMS 22 international Rockbowl contest,
- AGM hosted in September,
- Presidential Banquet and awards ceremony held in November which was attended by approximately 220 persons,
- Various webinars covering areas of interests selected by the members (i.e. seismicity, education, deep mining strategies and support methods),
- Various golf days.

SANIRE communicates through a quarterly newsletter, the SANIRE website and social media. 📌

## 13 ASIA

Suseno Kramadibrata | Vice President for Asia

ISRM Asia Region currently has 13 national groups. Sri Lanka joined the ISRM as the newest National Group since October 2022. Iran is no longer affiliated with the ISRM national group earlier this year. In 2022, some Asian countries still face the Covid-19 pandemic with relatively lower infection rate than the previous year. Despite the fact some of activities continues, other activities have still been impacted. The 12th Asian Rock Mechanics Symposium (ARMS12) was held successfully in Hanoi Vietnam. However, several national groups were still unable to send their representatives due to regulations on restrictions of leaving the country, such as China, Japan, Malaysia, & Singapore. There also have been several regional activities in the period. This report summarizes the 2022 ISRM activities in Asia

### CHINA

Main activities include China Rock 2022 that was successfully held in Beijing on 3-6 November 2022, the 11th Asian Rock Mechanics Symposium (ARMS11) "Opportunities and Challenges in Rock Mechanics and Engineering", was held at Jiuhua Resort & Convention Center in Beijing, China, on 22-24 October 2021, the 6th Early Career Forum was successfully held during ARMS11 on 23 October 2021, the second presidential meeting between Prof. Manchao He, the President of the Chinese Society for Rock Mechanics and Engineering (CSRME), and Dr. Gang Han, the President of the American Rock Mechanics Association (ARMA) on 30 January 2022, then the third Hotline between CSRME and ARMA Presidents on 22 October 2022.

Moreover, the International Correlation Research Program "Cross-Fault Measurement for Earthquake Prediction" was established in the International Consortium on Geo-disaster Reduction (ICGdR) on 1 April 2022, in Beijing, 24th Annual Meeting of the China Association for Science and Technology "High-level Forum on National Innovation Platform Construction" on 26 June 2022, the 10th Sino-Russian Deep Rock Mechanics and Engineering High-level Forum" was successfully held online from 25 – 26 June 2022, and the 4th International Conference on Rock Dynamics and Applications (RocDyn-4), an ISRM Specialized Conference, was successfully held in Xuzhou, China, on 17-19 August 2022.

Furthermore, the International Consortium on Geo-disaster Reduction (ICGdR) held the second council representative meeting of the year through video conference on 16 August 2022, and academician Prof. Manchao He, was successfully elected as Vice President from Experts, one of the five vice presidents of ICGdR (2022-2023). On 3 March 2022, the CSRME and Keai Press signed a cooperation agreement on the Journal of "Rock Mechanics Bulletin", the signing meeting and ceremony was held in Beijing. China National Group has several online lecturers: video course of Rockburst in Deep Tunnels by Prof. Xia-Ting Feng on ISRM website, Tsinghua University Seminar Series on Rock Mechanics in 2022, the lecture jointly held by Tsinghua University and the Chinese Society of Rock Mechanics

and Engineering, and Professor Chun Zhu from Hohai University (China) gave an invited talk on the 7th ISRM Young Members' Seminar on 29 Juli 2022.

Individual membership of NG China grew up from 2511 in 2021 to 2762 in 2022 with 27 corporate members. Since March 2020, CSRME has published Newsletter. It includes all the related works of CSRME.

### INDIA

Indian National Group is adopting new initiatives and strategies to serve their members as per their customized requirements. Online activities are their attempts in this direction. Main activities include (1) Virtual Training Program on Rock Excavation Tests for Mechanized Tunnelling, from TBM perspective, on 31 January 2022 with renowned expert Prof. V.M.S.R. Murthy and (2) Virtual Training Program on Use of Geosynthetics in rock engineering projects/seepage control in underground structures/tunnels on 18 February 2022 with renowned expert Mr. Vivek Kapadia.

The objective of the Virtual Training Program in rock excavation is focus in mechanized tunnelling, both in civil and mining sectors, is on continuous cutting edge technology such as TBM, road header, and continuous miners. The objective of the Virtual Training Program in Geo-synthetics have been widely used in various applications in the field of civil engineering and have proven effective in addressing several difficult problems.

As a part of celebration of 75th year of Indian Independence, ISRM India and National Institute of Rock Mechanics (NIRM) is organizing a weekly web-based online lecture Series on Rock Mechanics catering to various facies of rock mechanics application areas. These lectures mostly cover the applied rock mechanics with case studies showing apt demonstration of rock mechanics and rock engineering. Indian National Group will be hosting 13th ISRM Asian Rock Mechanics Symposium (ARMS13) in 2024.

Out of the 249 members in the year 2021, 230 members have renewed their membership/joined the ISRM as individual members, as on date, for the year 2022. The

Indian National Group of ISRM publishes Technical Journal - ISRM (India) Journal, on half yearly basis (January – June and July – December), since January 2012. The Journal has both print and online versions.

#### INDONESIA

Main activities include visiting lectures at universities in Indonesia regarding Rock Mechanic and Rock Engineering, the ISRM Glossary of Rock Mechanics terms have been translated by the Indonesian Rock Mechanics Society (IRMS) from an original list in English into Indonesian language, and IRMS is involved in the 6th Drill & Blast Conference 2022, on 5-6 July 2022 in Bandung.

Forthcoming events such as IRMS & Perhapi (Indonesian Mining Professional) will hold webinar series with subject of mining geotechnics and case studies of big slope failure in mines in Indonesia, and translation of ISRM suggested method into Indonesian language, Joint Conference between Indonesia National Group and Malaysia National Group on Rock Engineering Symposium (MIREs) will be held in 2023, and the 5th Workshop & Seminar National Geomechanics in 2023. In 2022, there were 57 individual members from Indonesia NG.

#### ISRAEL

Main activities include IRMA organized special session on geo-hazards within the frame of the Israel Geological Society annual meeting on 5-6 April 2022. The session covered topics in seismic hazard evaluation, Rock Mechanics and Geomechanics, and IRMA members teach Rock Mechanics / Rock Engineering courses in the master degree track in Geotechnical Engineering at the Department of Structural Engineering at Ben Gurion University. This track was developed by members of IRMA, in light of ever-increasing demand for engineers in the infrastructure industry, and emphasize on hard rock tunneling. ISRM membership of Israel NG is 15 members.

#### JAPAN

Main activities include selecting Excellent Paper Award & Excellent Doctoral Dissertation Award for JSRM Awards annually, the 48th Symposium on Rock Mechanics was held virtually on 12-13 January 2022 organized by Japan Society of Civil Engineers (JSCE) with the support of JSRM, the 27th Symposium on Underground Space was held virtually on 20 January 2022 organized by Japan Society of Civil Engineers (JSCE) with the support of JSRM, and Basic Course on Rock Mechanics, was held five times from 19 November 2021 to 7 January 2022, the lectures were held jointly with Japan Society of Civil Engineers (JSCE).

In 2022, a Special Committee for Revitalization Planning was newly established to revitalize the JSRM, and scholarship for student to participate at the 3rd International Conference on Coupled Processes in

Fractured Geological Media: Observation, Modeling, and Application (CouFrac2022) held in Berkeley, USA.

For information, JSRM has JSRM News Magazine and Rock Net mail news. In 2022, there were 36 corporate members and 325 individual members from Japan NG.

#### KOREA

Main activities include Spring Conference 2022, research & technology in rock mechanics & rock engineering on 31 March – 1 April 2022 in Kangwon National University and Fall Conference 2021 on 28 - 29 October 2021 in Busan BEXCO. KSRM organizes national conferences twice a year, which usually attracts around 150 participants. The 2021 Fall Conference was a joint symposium with other Korean academic societies of the Korean Society of Mineral and Energy Resources Engineers, Korea Society of Earth and Exploration Geophysicists, and Korea Society of Petroleum Engineers. The 2022 Spring Conference provided keynote lectures, special sessions, and academic sessions to discuss and share state-of-the-art research and technology in rock mechanics and rock engineering.

KSRM publishes an official bi-monthly journal in Korean, Journal of Korean Society for Rock Mechanics (Tunnel and Underground Space) and a quarterly electronic newsletter, 'U-Space' to inform and promote the state-of-the-art technologies in rock mechanics both home and foreign countries. KSRM jointly publishes two international journals in addition to Korean journals, quarterly published 'International Journal of Geo-Engineering' and bi-monthly published 'Geosystem Engineering', both being Open Access and indexed in ESCI. In 2022, KSRM has 180 registered individual members and 8 corporate members for ISRM.

#### MALAYSIA

Main activities include Rockworks by Rockware: Theory & Practical, Introduction of Geological Modelling, on 21-22 June 2021, Expert Panel Discussion on Seismic Hazard in Malaysia, on 8 July 2021, Forum on Soil and Rock Description for Civil Engineering Purpose in Malaysia, on 10 July 2021, Engineering Geological Model: Technical Paper Review by New Graduates, on 12 August 2021, SEGRM Virtual Open Day, Forum on Young Geoprotectionals in Rock Engineering & Engineering Geology, on 14 August 2021, the 5th SEGRM AGM & Pre AGM Talk, on 14 August 2021, Webinar on Sediment-Related Disaster Risk Reduction: From Mapping & Modelling to Early Warning & Mitigation, on 29 August 2021, Dr. Tajul Anuar Jamaludin Memorial Seminar, Case Histories in Engineering Geology & Rock Engineering, on 11 September 2021, GeoXPDC Bentong-Raub Suture, on 18-20 March 2022, SEGRM Talk Series, on 9 April 2022.

The Malaysian National Group of ISRM publishes MyRock Bulletin, free access at <https://www.segrm.org>. In 2022, Malaysia NG has 54 registered individual members and one corporate members for ISRM.



## 13 MONGOLIA

No report of 2022 activities.

### NEPAL

Main activities include 1st International Conference on Space Utilization and Research in Underground Structure (SURUng-I), on 5-6 May 2022, in Kathmandu, Technical Talk Series on Tunnel Engineering Practice in Nepal Himalaya in early 2022, contribution to Tunnel Engineering Curriculum in Tribhuvan University, Master Degree Course in Rock and Tunnel Engineering, and involve in research work on Technical Investigation in Tunnel Support Technology in Hydropower Project in the Himalayan Region.

### SINGAPORE

Main activities include monthly webinars for its members and the industry, from 6 September 2021 to 24 June 2022, 13th Asian Regional Conference of International Association for Engineering Geology/IAEG (ARC-13), on

16-18 November 2021, Workshop on Engineering Geology 2021, 30 November 2021, by video conference, the 17th SRMEG AGM, 11 March 2022, and short course on Site Investigation for Rock Engineering, on 22 April 2022. Forthcoming events include 18th Conference of the Associated research Centers for the Urban Underground Space (ACUUS 2023 Singapore), on 1-3 November 2023. In 2022, Singapore National Group has 89 registered individual members and 6 corporate members for ISRM.

### SOUTH EAST ASIA

Not report of 2022 activities.

### VIETNAM

Main activities include VIETROCK2021 in Ba Ria City, Ba Ria-Vung Tau Province, on 16 October 2021, and ARMS12 ISRM Regional Symposium, in Hanoi, on 22-26 Nov 2022. In 2022, Vietnam National Group has 21 registered individual members. ▀

## AUSTRALASIA

Sevda Dehkhoda | Vice President for Australasia

### INTRODUCTION

The two national groups for Australasia are:



**AUSTRALIAN  
GEOMECHANICS  
SOCIETY**

Australian Geomechanics Society (AGS)

442 individual members

4 corporate members

Chair: David Lacey 2022-24



**NEW ZEALAND  
GEOTECHNICAL  
SOCIETY INC**

New Zealand Geotechnical Society (NZGS)

235 individual members

Chair: Eleni Gkeli 2022-24

ISRM Liaison: Paul Horrey

AGS and NZGS are technical societies of National Engineering Institutions:

- Engineers Australia
- Engineering New Zealand

The two societies operate similarly through regional chapters. General activities of the two societies include:

- Local chapter/branch meetings
- Monthly technical seminars by Professionals
- Distinguished Speakers Series (coordinated by both NZGS and AGS national committees for arranging the tours, ie UK Rankine Lecture winners)
- Annual Chapters and National symposiums
- Workshops and courses (Engineering geology, Geotechnical mapping, Core logging)
- Students focused events; and
- Coordination of national standard reviews

The societies reach and attract young members by providing free membership for undergraduate students and heavily discounting the membership fees for

graduate students. Several chapters have dedicated annual student events and awards for final year thesis presentations as well as networking events for students to meet and greet with professional engineers. In addition, NZGS have formed Young Geotechnical Professional (YGP) Representative role, which is co-opted to the NZGS national management committee. This is an opportunity for YGPs to get involved with and contribute to the NZGS, as well as interacting with the wider NZ geotechnical community. The two societies are also National Groups for:

- International Society for Soil Mechanics Geotechnical Engineering
- International Association for Engineering Geology and Environment

### PUBLICATIONS

The regular publications of the two societies are:

- Australian Geomechanics Journal, published quarterly
- New Zealand Geomechanics News, published twice a year
- Local symposium proceedings

The current issues of the journals are shown below. Members can directly download the contents from the official websites of the societies. The journals can also be purchased by contacting society secretariates.

## ACTIVITIES IN 2022

### Selected AGS events:

<https://australiangeomechanics.org>



Generation and propagation of rock blast-induced pore pressures in quick clay

Reducing whole-life carbon as a geotechnical designer

2021 Queensland Symposium  
QLD Geotechnics - Major Projects and Innovations

Geothermal Energy and the Role of the Geotechnical Professional

Multi-phasic Approaches for Modelling Multi-Physics Processes in Complex Rocks

Suburban Rail Loop - Ground Conditions and Tunnelling Challenges

Rock Crushers and Low Speed Sizers: Design and Applications

Webinar: Geomechanical Characterisation of Grey Wacke

Fragmentation of rocks upon impact in the context of rockfall

7th International Young Geotechnical Engineers Conference

AGS WA Symposium 2022  
Engineering Geology and Geotechnics of Western Australia

Urban Underground Climate Change and the Use of Energy-geostructures



### Selected NZGS events:

<https://www.nzgs.org>

#### Geotechnical Engineering Basics Posters:

Initiated by the NZGS Young Geotechnical Professional (YGP) group, the idea behind these posters is to 'bridge the gap' between university assessment style theory and operating in industry general practice.

Each poster has a theme and are expected to reference each other within its final iteration. The posters are intended to be simple, follow a logical process, and capture 80% of our day-to-day processes as geo-professionals.

THE IMPORTANCE OF FIELD TESTING

The (R)Evolution of Monitoring

"Static Plate Load Testing With DIN 18134:2012-04: From CBR And Density To Stiffness Approach"

The NZGS 2022 Geomechanics Lecture - The Question of Risk

NZGS Webinar: Mine Subsidence: Cause, Effect, Mitigation

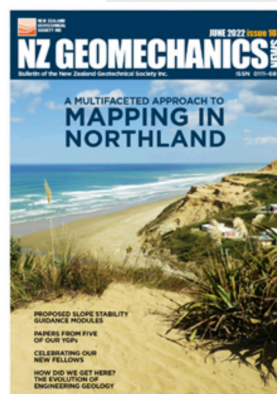
### NZGS Climate Change Symposium

Lessons to be Learnt | 1 - Abbotsford Landslip Disaster

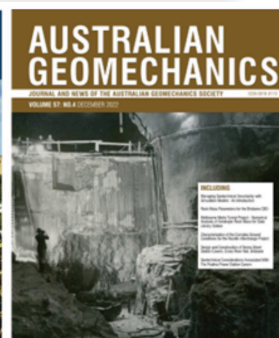
NON-INVASIVE SUBSURFACE SITE CHARACTERIZATION

Regional Young Geotech Professional (YGP) Mini Symposia

Earthquake Geotechnical Engineering Practice Series (a combined NZGS/NZ Government initiative)



NZ Geomechanics News  
Issue 110  
June 2021



Australian Geomechanics Journal  
Volume 57, Number 4  
December 2022

## 13 EUROPE

Leandro Alejano | Vice-President for Europe

Europe is the region encompassing half of the National Groups (NGs) of the ISRM with 30 countries represented. Due to their idiosyncratic, historical and linguistic differences, they are rather heterogeneous. Moreover, the NGs focus different disciplines. While in some cases, they are restricted to rock mechanics, in some countries they are part or a branch of a wider typically geotechnical or other type (tunneling, mining) society.

In the last year, Europe was coming out of the Covid-19 times, so whereas many activities were performed in an on-line manner in 2021, 2022 has seen the coming back of face-to-face meetings and conferences.

The main annual event of the European ISRM National Groups is the EUROCK symposium.

The EUROCK 2021 took place in 21-24 September 2021 in Turin, Italy in a virtual manner. 215 peer-reviewed papers published and 250 delegates attended. Relevant keynotes were presented. Various awards delivered including Rocha medal lectures and Franklin lectures to Fredrik Johanson (Sweden) and Rita Migliazza (Italy). Also, a tribute to Giovanni Barla was featured and the 5th Early Career Forum delayed from EUROCK 2020 was held coordinated by Jovan Jovicic.

The Finnish NG successfully organized the EUROCK 2022 symposium in Espoo on September, 2022. Around 200 papers were accepted corresponding to two tracks, namely scientific and industry, and around 300 delegates attended. Some interesting short courses were given the day before the congress. They included Modern Rock Engineering Principles (John Harrison and John Cosgrove), 2D and 3D Modelling of Fracturing Processes in Rock Mechanics (Omid Mahabadi & Bryan Tatone), Photogrammetry for Rock Mass Characterization (Mateusz Janiszewski & Lauri Uotinen). Four keynote lectures were delivered by John Harrison, Michael Giovinazzo, Caroline Darcel and Sanna Mustonen. Some excursions took place after the congress. This was a successful event where the European rock mechanics community were able to meet in person again.

On 2023 there will be not EUROCK, since the International ISRM will take place in Salzburg (Austria), organized by the Austrian National Group. Around 60 years ago, a few

rock mechanics experts gathered by Professor Müller in Austria decided to launch the ISRM. So, rock mechanics is coming back to its very cradle. We invite all European and International ISRM members to actively participating in this congress.

Additionally, last year it was decided to select Alicante in Spain as the venue of the EUROCK 2024, and in the recent Board Meeting, Trondheim in Norway was chosen to hold EUROCK 2025. It is worthy to mention that Norwegian National group tried to organize EUROCK 2020 that was finally cancelled due to pandemics.

In order to link the European NGs, the ISRM VP for Europe organized a council informal meeting in June 2021, where, Charlie C. Li, from Norway, suggested organizing European Rock Mechanics Debates. A last council informal meeting was also hold in parallel with International ISRM symposium in October 2022 in Asunción, Paraguay.

Based on the above mentioned initiative, the ISRM VP for Europe with the help of Philippe Vaskou from France and Charlie Li, from Norway, organized and developed the First Rock Mechanics European Debate in zoom in October 2021 on the topic "Using Hydraulic Fracturing to measure in situ stresses". This event was moderated by Philippe Vaskou and featured presentations by Gerd Klee (Germany) and Arne Marius Raen from Norway. It was hold in the Zoom platform and broadcasted through the newly launched ISRM YouTube channel, where it can be revisited. A second debate entitled "What model for what application in rock mechanics?" was held in Zoom in June 2022 with presentations by Heinz Konietzky from Germany and Jonny Sjöberg from Sweden. New seminars will be coming at the expected pace of 2 per year. These seminars are thought to be interested for technical and educational purposes and have receive some hundreds of visualizations in the ISRM Youtube channel.

Some European NGs (France, Italy, Spain...) encouraged a year ago young members to organize international webinars. These activities have continued and increased under the umbrella of ISRM's Young group with a strong participation of the European NGs' members.

The activities developed by European ISRM NGs are varied. The 2-3 most relevant activities of European NGs are synthetized in the following table, based on the answers of ISRM NG's Presidents to a call sent by the ISRM VP. 🇳🇵

### NG SOME RELEVANT ACTIVITIES

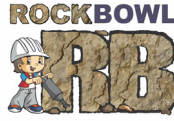
AUSTRIA	Organization of ISRM 2023.
BELGIUM	29/3/2022: on-line conference by C. David and D. Geremia (CY-Cergy University) "Water weakening and fluid-rock interactions on chalk from the Mons basin". 9/9/2022 : celebration of the jubilee "50 Years of Engineering Geology and Rock Mechanics in Belgium", Brussels (Atomium).
BOSNIA-HERZ.	Geotechnical Society of Bosnia and Herzegovina distributed first and second announcement of the GEO-EXPO 2022 scientific and expert conference which is to be held in Prijedor, Bosnia and Herzegovina, on October 21, 2022. Geotechnical Society of Bosnia and Herzegovina published proceedings of the scientific and expert conference GEO-EXPO 2021, although the symposium was not held due to Covid-19.



CZECH REPUBLIC	to Jon Justo Urrutia (Cantabria University) for his PhD thesis "Fracture assessment of notched rocks under different loading and temperature conditions using local criteria". International conference - New Knowledge and Measurements in Seismology, Engineering Geophysics and Geotechnical Engineering, March 29-30, 2022 .
FINLAND	Organization of Eurock 2022 in Finland from 12.-15.9.2022. Organization of short courses, and excursions in parallel with this event.
FRANCE	Organization of technical and scientific meetings. March 3: characterization and modeling of discontinuities in rock masses, May 5: applications of Artificial Intelligence methods in Rock Mechanics, October 27: applications of interferometry in Rock Mechanics. December 1: General Assembly and 2022 Jean Mandel Lecture "New challenges of landslides and ground movements" by A.M. Ferrero. 4 issues of the Revue Française de Géotechnique. CFMR awards the Pierre Londe prize to a young doctor. The 11th National Conference on Geotechnics and Engineering Geology (JNGG 2022) organized by CFMR, CFMS and CFGI on June 2022.
GERMANY	37th Baugrundtagung from 05 - 07.10.2022 in Wiesbaden as a face-to-face event.
GREECE	13th Athenian Lecture, 14/9/2022, University of West Attica, by Prof. Emer. K. Pitilakis (VP of EAEE): "Evolution of seismic design actions in Greece: From the 1955 map to the proposed new seismic hazard map with new site amplification factors and site classification scheme". Implementation of the "Time Capsule Project": Final Report by Dr. S. Cavounidis, former President of the HSSMGE. Theme: Geotechnical engineering & infrastructure in Greece. Available at: <a href="http://www.hssmge.gr/2022_2_HELLENIC-SSMGE-CAVOUNIDIS.pdf">http://www.hssmge.gr/2022_2_HELLENIC-SSMGE-CAVOUNIDIS.pdf</a> .
ICELAND	Approx. 3 meetings on general geotechnical topics. Iceland will be the host of the 4th Nordic Symposium on Rock Mechanics and Rock Engineering, in Reykjavik, May 24-26 2023. Preparation activities are under development.
ITALY	Course on: Geotechnical Models for Slope Stability of excavation faces in rock masses: from theory to case studies – 24 November 2022. Geotechnical Models for Slope Stability of excavation faces in rock masses: from theory to case studies. Chair: Prof. Tatiana Rotonda. 24 November 2022.
MACEDONIA	Organized 5th Symposium of MAG as an ISRM Specialized Conference (first one under ISRM fully held physically after the pandemic). Conducted survey and prepared "Time Capsule Project" considering Macedonian geotechnics in the past, present and future Preparing Price List of engineering services in geotechnics.
THE NETHERLANDS	18 February 2022- Online invited lecture: Environmental impact assessment of gas extraction below the Wadden Sea by Dr Robert Hack, Bigbonzoconsulting, formerly Univ. Twente, ITC (retired). 18 May 2022- Ingeokring-TU Delft symposium dedicated to Wim Verwaal for his 40 years of excellent contribution to the education of Engineering Geology in the Netherlands and beyond.
NORWAY	Stability and securing of rock cuttings (137 participants). Spring seminar 2022 - Tsension anchorage in rock (63 participants). Various Board meeting where it was decided to apply for EUROCK 2025.
PORTUGAL	Celebrations of 50 years of SPG - Seminar "Geotechnics as a reference for Portuguese Engineering" (November 2022) The XXXIX Manuel Rocha Lecture by Dr. Luís Lamas entitled "Determination of the stress state in rock masses for the design of underground structures" (October 2022).
SLOVENIA	Excursion with lectures: Geotechnical challenges in the construction of the Karavanke tunnel, 8.7.2022.
SPAIN	XIX Annual SEMR Meeting: Lab testing in rock mechanics: young res-earchers. 2022 (J. Justo, A. Rabat, I. Pérez-Rey, A. Muñoz, M. Muñoz). The 9th best research by a young member SEMR Award. The SEMR board named Professor Anotonio Gens (Barcelona School of Civil Engineering, UPC) as an Honored Fellow of the Society. XI National Symposium on Geot. Engineering, in Mieres, Asturias, May, 2022.
SWITZERLAND	12th May 2022 Conference on "Geotechnical Challenges in Soft Soils" in Muttentz, Switzerland.
TURKEY	ROCKMEC'2022 13 th Regional Rock Mechanics Symposium is held in in Isparta, Turkey on May 26 and 28, 2022 The symposium is organized by Süleyman Demirel University Mining Engineering Department with great success under the auspices of Turkish NG for Rock Mechanics. Turkish NG Chairman and members who contributed to Rock Mechanics were awarded.
UNITED KINGDOM	BGA announces Geo-Resilience 2023 conference: It will take place in Cardiff on 28-29 March 2023. (Announced on the 31/07/22). Call for abstracts now open.

## 13 LATIN AMERICA

José Pavón | Vice President for Latin America



The ISRM Latin American region has nine National Groups with over than 500 members, from Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Mexico, Paraguay, and Peru. These members include academics, practitioners, and students, involved daily in rock mechanics.

The interaction between societies has been fundamental during 2022. Moreover, regular regionals meetings have been involved the societies representatives to discuss the main activities and plan for the future ahead. The last one was face-to-face on the occasion of the Latin American Rock Mechanics Symposium (LARMS).

The 2022 ISRM International Symposium - LARMS IX – was held from October 16 to 19 at the Bourbon Hotel, Asuncion - Paraguay. The event gathered 170 participants from 31 countries, and a total of 71 papers were presented, divided into 10 technical sessions, and distinguished experts delivered seven keynote lectures. It is important to highlight the Early Career Forum, which involved all the young attendees, with 9 participants from Latin America, and the "Rock Bowl" competition between universities team, both carried out with great success. At the Closing Ceremony, the Award for "Best Papers" (General and Youth Categories) were delivered. The "Milton Kanji" Award, from the Paraguayan Geotechnical Society, for the Best Master's Thesis was chosen among six candidates, and the winner - Danny Rodriguez - was chosen by the Committee of Former Vice Presidents of the region.

New efforts have been made in order to increase the number of National Groups in the region, considering the potential of this part of the world. We expect good results in the near future.

The technical events started with online meetings and during the year move forward to face-to-face meeting. The most important activities of the societies of the region are described below:

### ARGENTINA

The activities were related to courses and seminars. The main one was held in November and the theme was "New Technologies for geotechnical monitoring in Engineering and Mining". The next congress will be in Comodoro Rivadavia City, next September. <http://saig.org.ar/congresos/>

## NORTH AMERICA

Laura Pyrak-Nolte | Vice President for North America

**North American Membership:** The total ISRM membership in North America is approximately 557 members. The US National Group, ARMA (American Rock Mechanics Association), has 417 ISRM members. The Canadian National group, CARMA (Canadian Rock Mechanics Association), has 150 ISRM members. Many members of ARMA & CARMA join or renew at the time of their annual symposia. Due to the COVID-19 pandemic, the 2020 and 2021 symposia were not held in person resulting in an overall decline in national group membership.

### BRAZIL

9th Brazilian Rock Mechanics Symposium, Campinas, August 23-26, 2022 (including 4th Rock Bowl Brazil) <https://cobramseg2022.com.br/>. Journals published quarterly and social media.

### BOLIVIA

Online presentations and Webinars: <https://www.geomecanicabolivia.com>

### CHILE

Online presentations and Webinars like "Geomechanical challenges. deep mass mining", November 30, 2022. <https://www.scmr.cl>

### COLOMBIA

Colombian Congress of Geotechnics, Cartagena, November 14-18, 2022.

Online presentations: <https://www.scg.org.co/>

### COSTA RICA

Repair and Restoration of Slopes - Mountain Roads, San Jose, Octubre 6-7, 2022

Online presentations: <https://www.geotecniacr.com>

### MEXICO

XXIII National Meeting on Geotechnical Engineering, Guadalajara, November 16-19, 2022

Journals published quarterly and social media. <http://www.smig.org.mx/>

### PARAGUAY

ISRM International Symposium - Latin American Rock Mechanics Symposium IX (LARMS IX), Asuncion, October 16-19, 2022. <https://larms2022.com/>

Rock Mechanics, course for young professionals with an emphasis on Geology, September, 2022.

### PERU

Peruvian Geoengineering Seminar, Lima, December 1-2, 2022.

Elements of seismic hazard in mines, short course, November 28, 2022. <http://speg.org.pe/>

## UNITED STATES OF AMERICA

ARMA represents the ISRM's National Group for the United States of America and currently has 712 active members. One third of its members are from outside the US and 15% of the members are students. The President of ARMA is Dr Gang Han (Aramco).

ARMA held its 56th US Rock Mechanics/Geomechanics Symposium (hybrid) in June 26-29, 2022 that included workshops on Damage Mechanics, Fiber Optics Sensing, Machine Learning, Induced Seismicity, Fundamentals of Rock Mechanics, CO<sub>2</sub> & H<sub>2</sub> and inducted 16 new future leaders. This was the first in-person symposium in three years. ARMA also held the 2022 International Geomechanics Symposium (IGS) on 7-10 November, 2022 in Abu Dhabi, UAE with 144 technical papers in 25 technical sessions 200 attendees from over 76 international organizations in 36 countries.

### ARMA HONORS AND AWARDS

**New ARMA Fellows:** Mark Board & John Curran

**ARMA 2021 Class of New Future Leaders:**

consists of 16 inductees: Marwah Alsinan, Jeff Burghardt, Danielli De Melo Moura, Radhika de Silva, Bing Hou, Wencheng Jin, Zoheir Khademian, Oladoyin Kolawole, Wei Li, Xiaofeng Li, Meng Meng, Jiehao Wang, Hui Wu, Qiquan Xiong, Sun Zhuang.

**Neville G. W. Cook Ph.D. Thesis Award:** Huang Yao, University of Pittsburgh: "Analysis of Sleeve Fracturing and Burst Experiments for Measurement of In-Situ Stress and Rock Fracture Toughness".

**M.Sc. Thesis Award:** Mustafa Can Suner, West Virginia University, "The Effect of Natural Fractures on the Mechanical Behavior of Limestone Pillars: A Synthetic Rock Mass Approach Application".

**Applied Research Award:** Yevengy Samarkin, Mahmoud Desouky, Murtada Aljawad, Abduljamiu Amao, Theis Soling, Khalid Al-Ramadan, Murtadha J. Al Tammar, Khalid M. Alruwaili (FRUPM & SAO): "Hydraulic Fracture Conductivity Sustenance in Carbonate Formations through Rock Strengthening by DAP Solution".

### ARMA ACTIVITIES

**ARMA Technical Committees:** There are currently 7 Technical Committees that include (1) Hydraulic Fracturing, (2) Induced Seismicity, (3) Drilling Mechanics and Engineering, (4) Underground Storage and Utilization, (5) Tunneling, (6) Discrete Fracture Networks, and (7) Artificial Intelligence and Data.

ARMA Fellows continued to mentor young ARMA members.

**ARMA Student Chapters:** Supporting engagement with the next generation of practitioners, ARMA now has 21 student chapter from Colorado School of Mines, Missouri University of Science and Technology, Texas Tech, Virginia Tech, The University of Texas at Austin, University of North Dakota, Monash University, University of Houston, University of Kentucky, Indian Institute of Technology (School of Mines), University of Texas/ Permian Basin, Texas A&M, Universidad Nacional de Colombia, and University of Toronto, China University of Petroleum Beijing, King Fahd University of Petroleum and Mining, King Abdullah University of Science and Technology,

Seoul National University, University of Wyoming, Waseda University, New Jersey Institute of Technology.

## CANADA

The CARMA represents the ISRM's 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). CARMA currently has 150 active members and the President of CARMA is Dr. Jennifer Day (Queens University).

RockEng22, the highly anticipated 22nd Canadian Rock Mechanics Symposium was held during August 8-10, 2022 in Kingston, Ontario with 150 delegates and was organized by Dr. Jennifer Day (Symposium Chair) and Dr. Mark Diederichs (Technical Chair). Other past and future CARMA related events include: (1) CIM AGM, Vancouver in May 2022; (2) GeoHazards8, the 8th Canadian Conference on Geotechnique and Natural Hazards – June 12th to 15th, 2022, Quebec City, QC, Canada; and (3) GeoCalgary 2022, the 75th Canadian Geotechnical Conference – October 2-5, 2022, Calgary, AB, Canada; (4) CIM 2023 Convention & Expo, Montreal, QC, April 30-May 1, 2023; (5) GeoSaskatoon 2023, the 76th Annual Canadian Geotechnical Conference – October 1-4, 2023, Saskatoon, SK, Canada.

In 2022, CARMA launched social media accounts on LinkedIn (694 followers) and Instagram (112 followers). New initiatives by CARMA include: (1) Website update to modernize the design, as well as to add both English and French languages (both Official Languages of Canada), (2) Create a Master's Thesis Award; (3) Create a Student Scholarship, and (4) Early-stage planning of the 23rd Canadian Rock Mechanics Symposium.

### CARMA HONOURS AND AWARDS

**1st Prof. Doug Stead PhD Thesis Award:** Dr. Jonathan Aubertin, Queen's University, thesis on "Characterization of rock salt response to blasting using terrestrial laser scanning technology".

**Best Poster Award RockEng22:** Apostolos Vasileiou, Matthew Perras for their poster on "Numerical and machine learning based approaches to study the influence of environmental conditions on crack growth in the Theban Necropolis, Egypt".

**The 2022 RES Rock Mechanics Awards:** Dave Mackintosh (Nutrien).

**The 2022 RES Best Student Poster Presentations:** 1st Place (Innovation in Rock Engineering): Mahdi Rabiei; 2nd Place: Negin Houshmand for her poster on "Rock hardness prediction using geophysical and geochemical data and machine learning".

**Activities by the Vice President for North America** Member, Scientific Advisory Committees, for EuroRock 2022 Finland and for the 4th CouFrac workshop 2022 at the ARMA annual symposium in Santa Fe, New Mexico. Held a Technical Oversight Committee meeting at Eurorock 2022 in Helsinki, Finland.

Gave the opening remarks at the 4th CouFrac Workshop in November 2023. 🌟



## 13 VICE-PRESIDENTS AT LARGE

Ömer Aydan  
Qiang Yang  
Vojkan Jovičić

In each term of office, the ISRM Statutes allow the Board to appoint a maximum of three Vice-Presidents at Large. Their role is to support their regional Vice-President and to contribute to the Board activities, to ISRM Committees and Commissions and sponsored events, and to assist the organizing commission of the sponsored events with their know-how.

Ömer Aydan served as the member of ISRM Technical Oversight Committee and evaluated the activities of ISRM commissions. He also participated in the online and face-to-face ISRM Board and Council meetings held in Asuncion, Paraguay, in October 2022. Besides he presented the report on Asian Continent and the evaluation report of TOC on ISRM Commissions in the Council meeting.

He encouraged his colleagues to contribute to 56th US Rock Mechanics/Geomechanics, EUROCK2022, International Symposium on Rock Dynamics (RocDyn4) and 48th Rock Mechanics Symposium of Japan in this difficult period due to Covid-19 besides his contributions. He delivered a keynote lecture at RocDyn4 - ISRM Specialized Symposium held on "Earthquake Prediction".

He has served as a moderator for the 37th ISRM online lecture 2022 by Emeritus Prof. Dr. Yuzo Ohnishi from Kyoto University, Japan entitled as "Evolution of numerical method for coupled problems in Rock Mechanics and Rock Engineering".

Ömer Aydan continued to write essays to convey the activities of ISRM to the digital newsletter of the Japanese Society for Rock Mechanics (JSRM), the Japanese National Group, denoted as "From the ISRM Vice-President". He has written three articles entitled "The utilization of new recent monitoring techniques for the advance of Rock Engineering: SAR and Laser Technologies", "The re-assessment of hazard associated with the possibility of rock cliff, rock slopes" and "Sinkholes and a proposal for their reflection in hazard assessment regulations" and a report on Board and Council Meetings held in Asuncion, Paraguay.

Ömer Aydan is also a member of the ISRM Planetary Rock Mechanics Commission and he has been promoting its activities. Within this regard, he participated in the panel discussion held during "Off-Earth Mining Forum-OEMF2022" and he has written some articles, specifically, on "Sinkhole Issues in Mars" in LARMS IX and "Some Thoughts on Rock Slope Issues in Mars" in EUROCK2022, "Some considerations on rock dynamics issues in Mars" in AUSROCK2022 and "Some attempts to infer mechanical properties of rock and discontinuities in Mars and some comets" in the Workshop organized by the ISRM PRMC in Melbourne in November, 2022.



Fig 1. Presentation at LARMS IX held in Asunción, Paraguay.

He has been promoting the activities of the ISRM Commission on Testing Methods as its member. He participated in the workshop of the Commission held in Helsinki before EUROCK2022 and delivered a possible new testing procedures on "Drop Weight Testing for Assessing the Dynamic Characteristics of Rocks Under Shock Loads" and he has been collaborating his colleague (Prof. T. Ito) on preparing another possible index testing technique on "Impression Creep Tests as Index Testing Technique in Rock Mechanics and Rock Engineering". He has been continuing to prepare a video lecture on "Rock Dynamics" as an ISRM Video Course. He has also been a member of the Underground Nuclear Power Plants Commission, and promoting its activities.

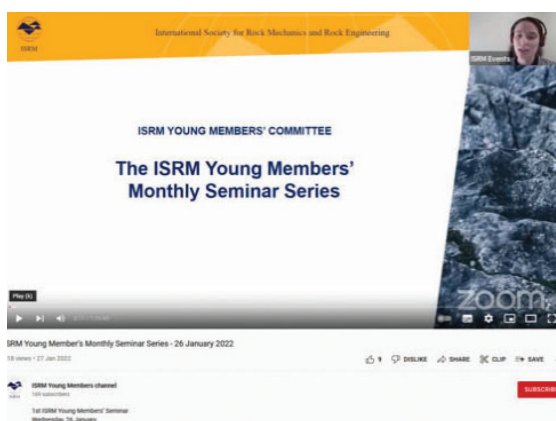
Ömer Aydan has been promoting new member countries and new members from Africa, Central Asia and Azerbaijan as new National Groups of ISRM.

He published a book on Earthquake Science and Engineering from a rock mechanics view point and he has been now planning to publish another book on "Geomechanical aspects of Abandoned Room and Pillar Mines and Remediation, which is now under review and will be published in the ISRM Book Series category.

This is the outline of activities that **Vojkan Jovičić** in 2022. It is divided into several main events he took part or organized, as follows:

### Activities at the YMC (Young Members Committee).

Vojkan Jovičić, VP of ISRM at large, took part on several sessions of the Committee on how to use advantages of new digital technologies and best approach young members of ISRM. As a result of the activities of Young



Members Committee an ISRM Young Members channel opened at You Tube in January 2022 with Monthly Seminar Series. So far, seven seminars has been delivered, all permanently available at You Tube.

Invited keynote lecturer on 5th Symposium of Macedonian Association for Geotechnics – ISRM Specialized Conference, June 2022

Vojkan Jovičić was a member of the organising committee of 5th Symposium of Macedonian Association for Geotechnics – ISRM Specialized Conference, which took place in June 2022. As an invited speaker, he delivered the keynote lecture on the topic: “Impact of Water Inflow and design solutions for construction of Karavanke Tunnel” and wrote a paper under the same name. The event was a regional conference that assembled around 200 attendees from 25 countries.

Invited keynote lecturer on 16th Symposium of Serbian Association of Structural Engineers, September 2022

As an invited speaker, Vojkan Jovičić, delivered the keynote lecture on the topic: “Geotechnical Aspects of Civil engineering” and wrote a paper under the same name. The event, organised by Association of Structural Engineers of Serbia took place in Arandjelovac, Serbia in September 2022. This was a regional conference that assembled around 300 attendees from 10 countries. Vojkan Jovičić, used this opportunity to inform the civil engineers from the region about the role and the mission of the ISRM and to invite them to participation.

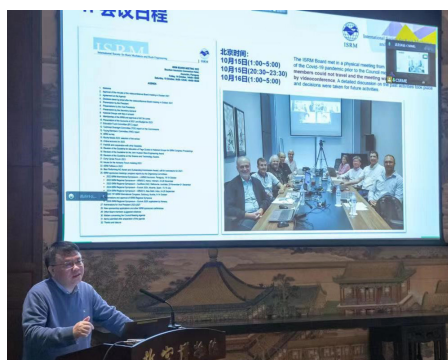
Invited keynote lecturer on ChinaRock2022 organised by China Society of Rock Mechanics and Engineering (CSRME), November 2022

As an invited speaker, Vojkan Jovičić delivered the keynote lecture on the topic: “ Temporary and Final Portal Structures for Tunnels in Soft Rock”. The lecture was delivered during the plenary session on 4th November. The annual conference was organised on-line by the NG of China (CSRME) and assembled engineers from Rock Mechanics related professions of PRC.

Qiang Yang is the Chairman of the Education Fund Committee. Other EFC members include Manchao He, Seokwon Jeon, José Pavón, Ismet Canbulat, and Luís Lamas. He has successfully raised a fund of 100 000 RMB (about \$15 450) to the EFC Beijing office. The 7th Early Career Forum chaired by José Pavón was successfully organized in 2022, and nine young engineers from Latin America participated in the forum. In addition, two EFC activities associated with AusRock 2022 were organized by Prof. Ismet Canbulat. A young professional focused webinar on Digitalisation and Integrated Visualisation was held on June 9, 2022, and a panel discussion on education, training, and professional development was arranged prior to the closure of AusRock 2022.

Qiang Yang served as the organizing committee chair of the ChinaRock 2022, which was virtually held on Nov. 3-6, in Beijing, China. There were 29 parallel sessions, 590 oral presentations, and 12 technical training courses. The technological innovation industrial exhibition attracted 100 exhibitors.

Qiang Yang was invited to attend the workshop on ISRM commissions organized by Chinese Society of Rock Mechanics and Engineering on Nov. 10, 2022. He presented the latest news of ISRM, and provided constructive suggestions on development of ISRM commissions led by Chinese researchers.



The seminar series on Rock Mechanics organized by Tsinghua University was virtually held from May to in October in 2022. This seminar series were initiated and organized by Prof. Qiang Yang and Assoc. Prof.

Zhihong Zhao from Tsinghua University. Five outstanding researchers including Dr. Jonny Rutqvist, Prof. Shemin Ge, Prof. Musharraf Zaman, Prof. Leandro R. Alejano, and Prof. Antony P.S. Selvadurai were invited to give presentations on theories, simulations and engineering applications related to rock mechanics rock engineering.



# 14 FRANKLIN LECTURE

W. Bilfinger | Vector Projetos Ltda., São Paulo, Brazil



## ROCK STRENGTH DEGRADATION IN TUNNELING

Although rock tunnels are often associated with hard rocks, where the rock mass behavior is governed by its discontinuities, almost all rocks present some form of time-dependent behavior. Typical time-dependent behavior is associated with swelling and slaking rocks, in which physicochemical reactions involving moisture and stress relief generate changes in the rock properties. Swelling rocks usually suffer significant volume changes; slaking rocks do not necessarily suffer volume changes, but strength degradation. Several tunnel projects around the world have suffered severe problems, such as delays and costs increases, making previous knowledge and adequate planning an important tool for designers and decision-makers. This paper focuses on rock strength degradation, its different mechanisms, available tests to predict the phenomena, and design recommendations.

### 1. INTRODUCTION

Tunneling in rocks is often associated with hard rocks, where rock mass behavior is primarily controlled by its discontinuities. Two of the most traditionally used rock classification methods, RMR (Bieniawski, 1989) and Q (Barton et al. 1974; NGI, 2015) are based on the discontinuities of the rock mass: spacing, orientation and characteristics (including roughness, weathering and fillings). Nevertheless, in some cases, the rock mass may present time-dependent behavior, changing its properties significantly over time. Although there are some attempts in the traditional rock mass classification methods to include this type of behavior, actual rock mass behavior often requires more complex approaches.

Typically, rocks with swelling and slaking behavior change their properties during tunnel construction or its design life, and the evaluation of the involved mechanisms, rock types, identification and quantification of effects on the tunnel is relevant. Squeezing rocks also have time-dependent behavior but associated to the type of rock and the stresses around the tunnel, and not to changes in properties (Carter et al, 2010).



Fig. 1 Typical slope stability problem associated to slaking rock. (Source: Photo taken by the author).

### 2. ROCK DEGRADATION

#### 2.1 Overview

Permanent changes of rock properties that reduce strength and increase deformability are usually associated with two different mechanisms: slaking (often called “accelerated weathering”) and swelling. Several problems related to these mechanisms are described in general rock mechanics. In all situations, moisture plays an important role.

A typical slope stability problem caused by the slaking of soft rocks can be seen in Figure 1. The road cut in the state of Santa Catarina, Brazil, shows interbedded layers of claystone and sandstone. The claystone layers show slaking behavior, breaking down in small pieces, and, in turn, generating destabilization of bigger blocks of the more stable sandstone layers.

Figure 2 shows an example of slaking basalt mapped in the state of Minas Gerais, Brazil. Weathering due to exposure is accelerated and generated severe slope stability and erosion problems.



Fig. 2. Slaking basalt in a road cut generating stability and erosion problems. (Source: Photo taken by the author).



Other problems associated to accelerated rock degradation can be found in several civil and mining engineering applications, showing that weathering of rocks is not always an issue associated with geological times, but may be relatively short termed.

## 2.2 Rock Degradation in Tunneling

In tunneling, different authors, summarized in Bilfinger (2022), describe lining collapses and damages to linings due to slaking and/or swelling behavior. An example of lining is presented in Figure 3.



Fig 3. View of damaged and overstressed tunnel lining, with cracks in the shotcrete and deformed anchor plates. (Source: Photo taken by the author).

Several mechanisms leading to time-dependent change of rock properties have been discussed by various researchers. Bell et al. (2000), Boniface (1999) and Broch (2010) describe rock degradation of basalts of the Lesotho Highlands Water Project by “crazing” – opening of microcracks due to the presence of swelling clay minerals in the rock matrix of basalts and access to water or moisture. The process of degradation is “self-perpetuating”, because of the advance of the cracks, allowing for access of water and swelling of clay minerals at greater depth.

Brattli & Broch (1995) describe failures at the Chingaza tunnel in Colombia in shales and siltstones. The failure mechanisms are attributed to an initial drying out of the rock in the stretches where a 5 to 15 cm thick shotcrete lining was installed. The drying out caused strength reduction and contact of the existing clay minerals to water, leading to swelling and progressive degradation of the lining and the surrounding rock. It is interesting to note that in the stretches where a circular unreinforced cast in place concrete lining was installed, no problems were observed.

Bilir (2011) presents data on stability problems, such as closure or floor heave of horseshoe shaped steel and concrete cross sections, in mining tunnels excavated in claystone in Turkey. Swelling tests performed on in situ material did not show swelling potential. After grounding and preparation of artificial samples by pressing, swelling pressures of up to 2.06 MPa were measured. Swelling potential was associated to smectite group clay minerals.

Piaggio et al (2017) and others discuss problems from various tunnels built in Chile through different rock types: reddish tuffs, volcanic siltstones, sandstones, breccia and conglomerates, andesitic-basaltic lava flows and shales. One of the difficulties was to identify the problematic rock stretches before excavation and in some case, exposure to water: swelling tests were in some cases inconclusive and the association of more than one test is described as necessary to properly identify critical stretches. Although variable swelling pressures of up to 1.5 MPa were measured in the laboratory, most pressures were under 1.0 MPa. Although measured swelling pressure is not usually high, these pressures and other chemical processes seem to have led to the transformation of relatively sound rock into soil-like material.

Marinos et al. (2013) describe the behavior of molassic rock in Greece, with slaking behavior of siltstones. Olivier (1990) discusses similar behavior of mudrocks in South Africa.

Steiner (1993) describes 11 tunnels excavated in shales in Switzerland, France, Italy and Canada, where swelling pressures were back calculated and usually varied between 0.1 and 0.3 MPa.

Steiner et al. (2010) present the analysis of different tunnels, tests and numerical models and conclude that, for brittle rock, damage initiates for a stress level of  $\sigma_{vmax}/UCS = 0.35$  to 0.5. In the case of swelling ground, brittle failure increases swelling potential or may even trigger swelling.

Few references describe strength deterioration due to swelling and slaking: Yoshida et al. (1997) present numerical modeling of strength deterioration of mudstones due to softening over time. Vergara & Triantafyllidis (2015; 2016) show results of tests on argillaceous rocks, where strength and stiffness decrease after swelling.

An example of rock properties degradation in gneissic rock was observed in a tunnel recently built in Brazil. During the construction, geological excavation front mapping registered high Q and RMR values at several locations. One year later, the tunnel was re-mapped and lower RMR and Q values were obtained at several locations. Approximately one year thereafter, the tunnel was re-mapped and, again, lower RMR and Q were obtained for some stretches. Geological descriptions of the rock degradation included:

- Block detachment due to weathering of biotite rich bands;
- Block detachment due to the combination of rock discontinuities, probably associated with weathering of the discontinuity surfaces;
- Weathering of the rock mass, specifically pegmatite with signs of hydrothermalism, transforming sound rock into soil-like material that could be hand-excavated.

Horizontal borehole cores drilled from the tunnel in one of the most critical regions are shown in Figure 4.

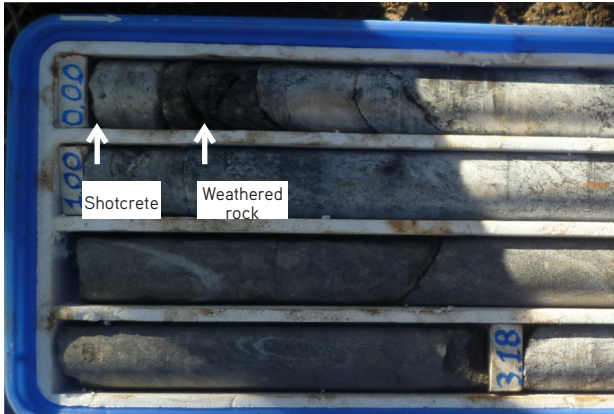


Fig 4. Horizontal borehole cores. Totally weathered rock in contact with the tunnel lining shotcrete. (Photo: personal file of the author).

Completely weathered rock can be identified in direct contact with the tunnel lining shotcrete.

Based on the analyzed cases and the experience of the author, at least three different types of behavior can be identified:

- Soft rock slaking: wetting and drying cycles degrading the rock into small pieces or lumps, destroying its structure progressively and transforming it into a soil like material. Swelling minerals may be present, but do not generate significant expansion. A typical example can be seen in Figure 1.
- Soft rock swelling: increase of moisture and/or decompression/stress relief generates chemical swelling, often associated with swelling clay minerals. In many cases, significant swelling pressures and/or expansion are generated. Typical examples are shales with significant swelling clay content.
- Hard rock slaking and swelling: increase of moisture content and decompression, associated with swelling clay minerals, “destroying” its structure. Expansive pressures and strains are not high in several cases, but the rock strength decreases sometimes drastically and deformability increases.

A characteristic behavior that all cases have in common is that the process of degradation is progressive: degradation and swelling lead to more access to water and additional swelling or slaking. Figure 5 shows a view of a tunnel wall, where degradation caused a “slabbing”-like behavior, with soil-like material between more sound rock slabs. The strength reduction leads to a localized failure of the lining, reduction of horizontal stresses and the possibility of continuity of the process, if no stabilizing actions are taken.

In tunnels with limited access for inspection and maintenance, such as hydro tunnels, this process often leads to significant degradation or full tunnel closure. Additionally, in hydro tunnels, swelling is often potentialized by unlimited access to water and additional direct erosive action.

One of the key unsolved issues when dealing with rock degradation and/or swelling rocks is identifying



Fig 5. Partial failure of tunnel lining due to degradation. (Photo: personal file of the author).

the location of critical stretches before excavation or exposure to moisture for a certain time. In some cases, the potentially swelling and degrading material is restricted to rock joints, and, in others, the swelling minerals are part of the rock matrix.

Even in the so-called “stable rock,” some rock strength degradation may occur. Cacciari (2014) describes an unlined railway tunnel excavated in gneiss between 1970 and 1980, where loose rock blocks must be periodically removed mechanically to avoid accidents. The same procedure of occasional rock block removal is necessary in unlined road tunnels excavated in granite and gneiss in the city of Rio de Janeiro, which is evidence that, to some extent, even rocks masses which are not known for slaking or swelling behavior suffer some type of strength degradation. These types of effects are not the focus of this paper.

### 3. TYPICAL MECHANISMS

#### 3.1 Slaking

Slaking is normally defined as “...the crumbling and disintegration of rock or hard soil upon exposure to air or water...” (ITA-AITES, 2022). This definition is supported by several authors (Franklin & Chandra, 1972; Goodman, 1993; Skrede, 2017), who describe slaking as short-term weathering or break down by wetting and drying.

Franklin & Chandra (1972) describe three factors that influence slake durability:

- Permeability and porosity, that control the entry, retention and mobility of fluids inside the rock;
- Action of fluids, once inside the rock: adsorption resulting in surface energy changes, solution of cements or disruption of bonds, or disruptive forces by pore-pressure generation;
- Capacity of the rock to resist disruptive forces.

Slaking mechanisms are complex and vary according to type of rock. In soft rocks, such as mudrock, the slaking mechanism is associated with changes in moisture content, where entrapped air due to capillary action is pressurized, leading to failure of the rock skeleton, according to Terzaghi & Peck (1948), Bell (2007), and

others. According to Pelissier & Vogler (1990), slaking is controlled by the interaction of the rock structure, permeability, matrix suction and swell of clay particles.

Fookes et al. (1988) stated that slake durability is conditioned by the following petrological tests: specific gravity, porosity, hardness, texture, moisture content and secondary mineral content.

Problems associated with slaking behavior are described for several sedimentary, metamorphic and igneous rock types (Bilfinger, 2022).

### 3.2 SWELLING

Swelling is usually defined as "...increase in volume upon exposure to water ..." (ITA-AITES, 2022). This definition is in line with other references, such as FHWA (2009). Galera et al. (2014) claim that swelling is associated with stress changes, increase in water content or the association of both phenomena.

Two main types of swelling processes are described (Pimentel, 2015):

- Physical mechanisms, associated with the presences of swelling clay minerals;
- Chemical mechanisms, due to the anhydrite-gypsum transformation or oxidation or the transformation of calcium carbonate to gypsum, due to the oxidation of pyrite (Brattli & Broch, 1995).

According to Skrede (2017), kaolinite, illite, smectite and vermiculite are the most common groups of clay minerals. Swelling behavior is usually associated to smectites, consisting mainly of subclasses that include montmorillonites, and vermiculites.

Anhydrites, when in contact with water, transform into gypsum by absorbing water molecules into its structure. This process leads to a volumetric increase of around 60% (Wittke-Gattermann & Wittke, 2003; Anagnostou et al., 2010). The transformation of calcium carbonate to gypsum, due to the presence of oxidized pyrite causes a volume increase of 23%. These types of swelling will not be further addressed in this paper.

Problems associated to swelling behavior are described for several sedimentary, metamorphic and igneous rock types (Bilfinger, 2022).

### 4. TESTS TO EVALUATE SLAKING AND SWELLING

There is consensus that more than one test is necessary to adequately characterize slaking and swelling potential. In this item, a list of the most commonly available tests is presented.

Initial assessments of swelling and/or slaking potential can be made using simple field tests, for instance, the smear test, taste test and water reaction test, as proposed in ISRM (1994).

An important pre-laboratory testing issue is sampling and storage of samples to be tested. Ideally, samples

should maintain the same density and water content as in their in-situ conditions, as outlined in ISRM (1989). Even though the ISRM recommendations were aimed at swelling rocks, they also apply to slaking rocks, in which changes in confinement and moisture can cause change of properties as well.

#### 4.1 Slaking

For the evaluation of slaking potential, the following tests are available:

- Slake Index Test: proposed by Deo (1972, as cited in Santi, 1998) and modified by Santi (1998);
- Slake durability test (SDT), proposed by Franklin & Chandra (1972) and described as suggested method in ISRM (1979);
- Jar slake test (Santi, 1998; Mohamad et al, 2011);
- Ethylene Glycol test (Paige-Green, 2008; van Blerk et al, 2016; Piaggio et al, 2017).
- ASTM D5313 (2021), method for evaluation of the durability of rock for erosion control under wetting and drying conditions.

Another test is described by Okamoto et al. (1981), where slaking is measured during wetting and drying cycles, under controlled temperatures. The described apparatus, however, does not seem to have been employed recently to investigate slaking.

The most common test to quantify slaking potential is the SDT. A SDT result is conventionally defined as the ratio between final to initial tested masses after 2 cycles of the test procedure ( $I_{D2}$  or  $I_d$ ). Slake durability can be classified according to Table 1:

Table 1. Variations of the SDT

Classification	Slake Durability $I_d$ (%)
Very Low	0 – 25%
Low	25 – 50%
Medium	50 – 75%
High	75 – 90%
Very High	90 – 95%
Extremely High	95 – 100

Some authors discuss if 2 cycles are adequate and often different number of cycles are tested and the obtained index is usually defined as  $I_D$  number of cycles. Other variations of the SDT and tests on samples after cycles of the SDT are also available and summarized in Bilfinger (2022).

Interesting test results, correlating SDT results with UCS, show that in general, "stronger" rocks, with higher UCS, are less affected by slaking and have higher  $I_{D2}$ . Figure 6 shows graphical regression results of the relation between UCS and  $I_{D2}$  for some rock types.



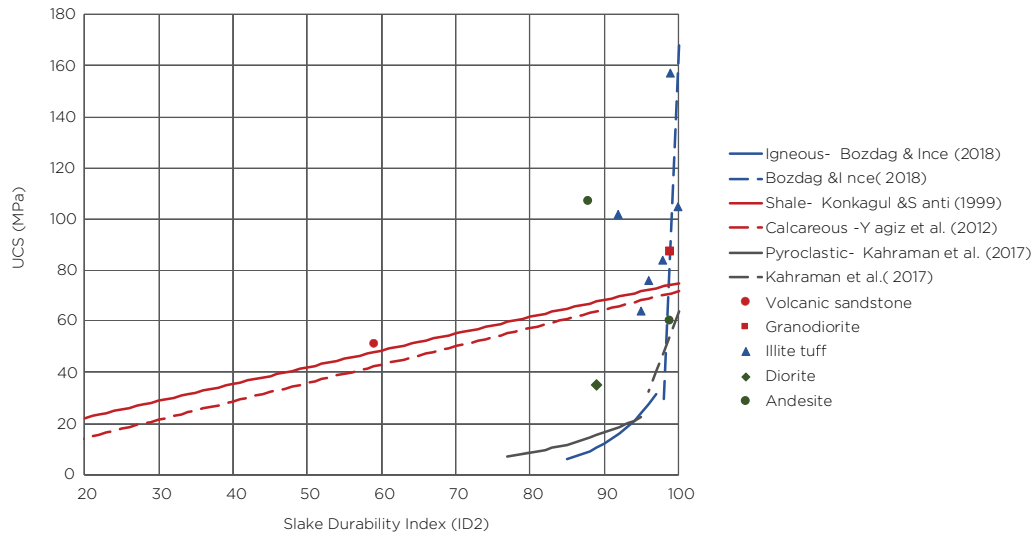


Fig 6. Regression results of the relation between UCS and ID2 for different rock types (including data from personal file).

Igneous rocks (Bozdag & Ince, 2018)

$$UCS = 6 \times 10^{-5} \times e^{0.1358(I_{D2})} \text{ for } I_{D2} < 98 \quad (1)$$

$$UCS = 69.267 \times I_{D2} - 6758.8 \text{ for } I_{D2} < 98 \quad (2)$$

Shales (Koncagül & Santi, 1999) – adjusted for MPa.

$$UCS = 0.658 \times I_{D2} + 9.081 \quad (3)$$

#### 4.2 Swelling

For the evaluation of swelling potential, the suggested laboratory test methods by the ISRM (1989) are:

- Determination of maximum axial (confined) swelling stress;
- Determination of maximum axial and radial free swelling strain;
- Determination of axial swelling stress as a function of swelling strain.

Additional relevant tests to identify swelling potential include:

- SEM, XRD, thin sections, to identify potentially swelling minerals;
- Ethylene Glycol test (Paige-Green, 2008; van Blerk et al, 2016; Piaggio et al, 2017);
- Huder-Amberg test (Huder & Amberg, 1970), a variation of axial swelling test as a function of swelling strain, which includes an unloading and reloading cycle, prior to sample saturation;
- Cyclic swelling tests, as described by Vergara & Triantafyllidis. (2015) and Selen et al. (2020);
- Powder swelling tests (Thuro, 1993; Rauh et al., 2006). Instead of testing “undisturbed” samples, in these tests milled rock is tested using ISRM suggested methods or as proposed by Rauh et al. (2006);
- Atterberg limits, to estimate clay mineral activity;.

Difficulties of quantifying swelling pressures and swelling potential become clear in the paper published

by Selen et al. (2018), which highlights significant differences of similar test results by two important laboratories.

#### 5. VARIATION OF UNIAXIAL COMPRESSIVE STRENGTH DUE TO WATER CONTENT

Uniaxial compressive strength (UCS) is one of the most important and common tests in rock mechanics. An ISRM-Suggested Method (SM) (Ulusay & Hudson, 2007) describes test details which, among others, include the recommendation to perform the test on samples not stored for longer than 30 days and under natural moisture conditions. The SM recognizes the importance of reporting the moisture content and of evaluating UCS for different moisture contents. Several authors present data of variable UCS results as a function of moisture content or for both “dry” and saturated tests. Studies by Vasarhelvi (2002) and Vasarhelyi & Van (2006) showed an approximately linear relationship between dry and saturated UCS for volcanic tuffs and sandstones:

Volcanic tuffs:

$$UCS_{(sat)} = 0.729UCS_{(dry)} \quad (4)$$

Sandstones:

$$UCS_{(sat)} = 0.759UCS_{(dry)} \quad (5)$$

Figure 7 presents a compilation of test results for different rock types under dry and saturated conditions reproduced from Bilfinger (2022). An almost identical general trend between dry and saturated UCS values identified by Vásárhelyi (2002) and Vásárhelyi & Van (2006) can be observed in equation (6), obtained from the results presented in Figure 7:

$$UCS_{(sat)} = 0.758UCS_{(dry)} \quad (6)$$

As showed in Figure 7, the UCS ratio varies for different rock types. For example, granite, marble, diabase and gneiss have an average ratio between UCS values above 75%. For shales, the ratio is around 30%. Romana & Vasarhelyi (2007) present similar

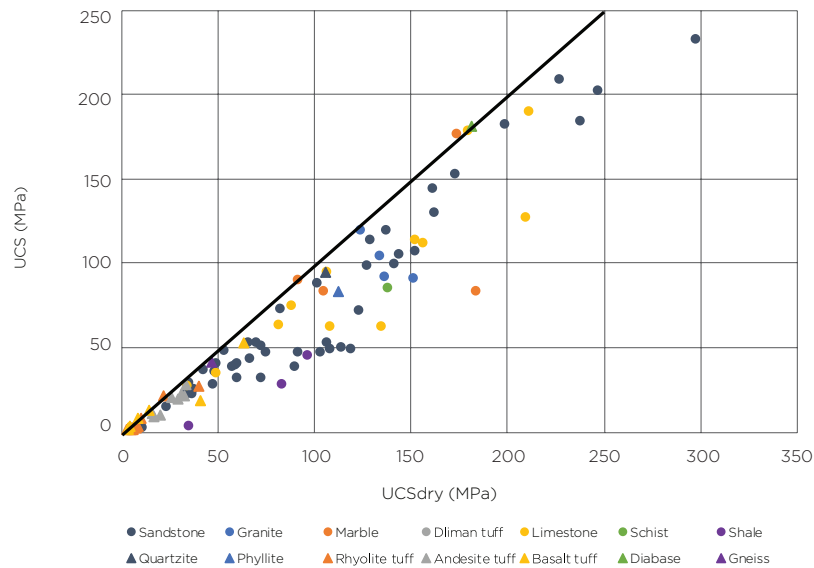


Fig 7. Compilation of UCSsat x UCSdry data

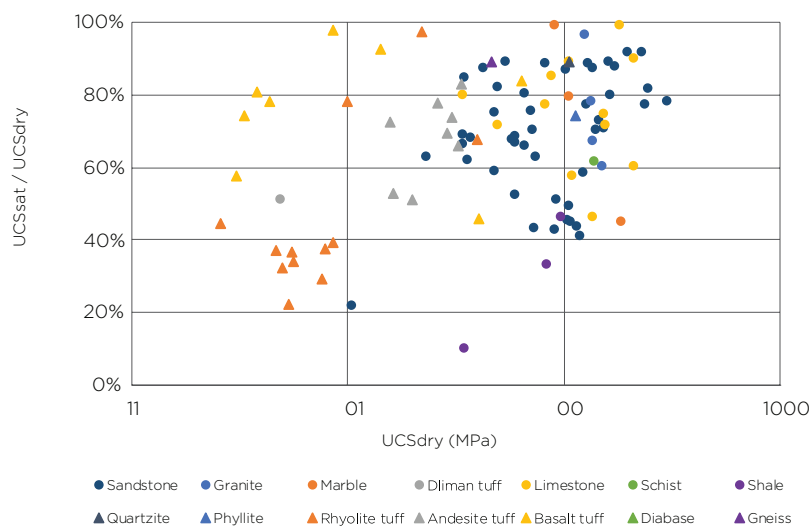


Fig 8. UCS x UCS sat / UCS dry ratio. Same data as in Figure 7.

conclusions regarding wet and dry UCS ratio: for strong rocks, the ratio varies between 80 and 90%, for medium strength rocks, between 60 and 70%, and for soft argillaceous rock, 30%.

Figure 8 presents the data of Figure 7, with the UCS ratio as a function of UCS.

The results presented above allow some general conclusions, which are aligned with the conclusions of Wong et al (2016):

- Sedimentary rocks usually show higher UCS reductions due to saturation than igneous rocks;
- Fine grained sedimentary rocks (e.g., shale) are usually more affected by saturation than sandstones;
- UCS reductions due to saturation is higher, in general, for rocks with lower UCS.

Jaeger et al. (2007) show that mechanical interaction is governed by the effective stress principle, and the difference between dry and saturated samples can be explained by the fact that samples often de-saturate and measured strength is artificially increased by suction (Amman et al., 2015). This type of interaction is, in principle, fully reversible.

Chemical interaction may also affect rock strength. Different fluids, and even different types of water, may change the rock strength (Ou, 2020; Vardé, 2020). Azhar et al. (2020) presents data of clay rich sandstone, where slake durability and elasticity modulus decreased after saturation for some time. A part of the clay minerals was identified as being montmorillonite, which is assumed to be the main cause of a reduction of over 90% of the elasticity modulus. Chemical interaction is, in general, not reversible.

## 14 6. DESIGN APPROACHES

### 6.1 Geological-geomechanical Model

The key to a successful project is the development of an adequate geological and geomechanical model. This model must be developed from early stages on and be continuously updated throughout the project. During early stages of the project, a comprehensive desktop study is necessary, including the evaluation of geological maps, literature and, more recently, readily available satellite images. The use of the concepts proposed by Fookes et al. (2000), with the construction of a geological model, evolving from a broader global view at tectonic scale to a more specific local geological model, is a practical and interesting proposal.

After desktop studies and evaluations, a walkover is fundamental, analyzing in detail local features and updating the model continuously and anticipating what conditions might be associated with the findings.

Based on previous findings, the model is continuously updated with results of an initial phase of ground investigations and, possibly, supplementary investigations. Ground investigations must be programmed according to the model. Programming, for example, boreholes with fixed spacings may not be ideal; location of boreholes should be evaluated so that possible geological features are investigated adequately.

The geological model must be continuously updated during construction, especially in the case of tunnels, where ground investigations are often limited due to several reasons, like high cover, limited representativeness of cores, between others. Geological mapping and testing during tunnel excavations is fundamental and, as previously discussed, many problems in tunneling works were detected only after tunnel excavation.

Fookes et al. (2000) states the following main guidelines for the construction of a geological model:

- Form an understanding of what is found from desktop studies;
- Anticipate what geology conditions might be associated with the findings;
- Develop this through subsequent stages of the investigation, design, and construction.

### 6.2 Rock Mass Classification Systems

Özkan et al. (2012) proposes a modification of the RMR classification system specifically for weak rock, called the M-RMR. This change has the main objective of including results of the SDI in the classification system, as well as adjusting some of the other parameters. Celada et al. (2014) discuss a reviewed RMR, which considers SDT results when computing RMR values. A similar approach for the Q-system was presented by Almenara (2020), where SRF values are suggested as a function of the SDT.

Rock mass classification systems, in general, do not take into consideration the change of rock properties with time. In the Q-System (Barton et al, 1974; NGI, 2015), the SRF factor is used to reduce Q by up to 15 times, if “heavy rock swelling pressure” is expected, which, in a certain way, can be compared to a Q reduction with time. However, in the opinion of the author, rock strength degradation may generate soil-like material, for which the rock mass classification systems and associated linings, are not appropriate.

### 6.3 Swelling

Grunicke & Walter (2004) and Wittke-Gattermann & Wittke (2003) discuss the implementation of a swelling law into FE codes, where uniaxial stress-swelling strain relation is approximated to be logarithmic. Using this approach, they concluded that simply applying a uniform swelling pressure on the lining might be non-conservative: lining stiffness seems to play an important role on the effect of swelling pressures on the lining.

Hawladar et al. (2005) introduce a model that incorporates test results of the Ontario shale, where swelling strain increases as a logarithmic function of time. Calibrations of the model agreed with monitoring results. Kramer & Moore (2005) discuss the implementation of swelling into FE modeling, in order to approach time-dependent behavior.

Schädlich et al. (2012) present the implementation of a swelling model, with a logarithmic swelling law for the stress-swelling strain behavior and an exponential decay of swelling strain with time, implemented into Plaxis.

John et al. (2009) discusses a practical approach, due to the high variability of swelling pressures of claystone along tunnel alignment of the Pfändertunnel in Austria: immediately after bench excavation, extensometers were installed, together with rock sampling and evaluating of its disintegration for 24 hours. Based on this information, the swelling potential was evaluated. Prestressed anchors were used to avoid tunnel invert heave along approximately 50% of the tunnel, with an average load of 0.13MPa. In addition, the rock surface was immediately sealed after excavation to avoid the access of water.

Amberg (2011), Ladanyi & Gill (1988) and Sulem et al. (1987) introduce a convergence-confinement approach including time-dependent behavior and circular tunnels, showing interesting results. Creeping rock, according to these authors, may include swelling potential.

Steiner (1993) describes tunnels excavated in shale, where most problems were solved by controlling deformations, often by installing an invert. He also concluded that swelling pressures usually vary between 0.1 and 0.3 MPa in shales

Several authors state that laboratory test results yield unrealistically high swelling pressures, when compared to the pressures acting on a tunnel. Nilsen (2016) proposes to use no more than 50% of the swelling



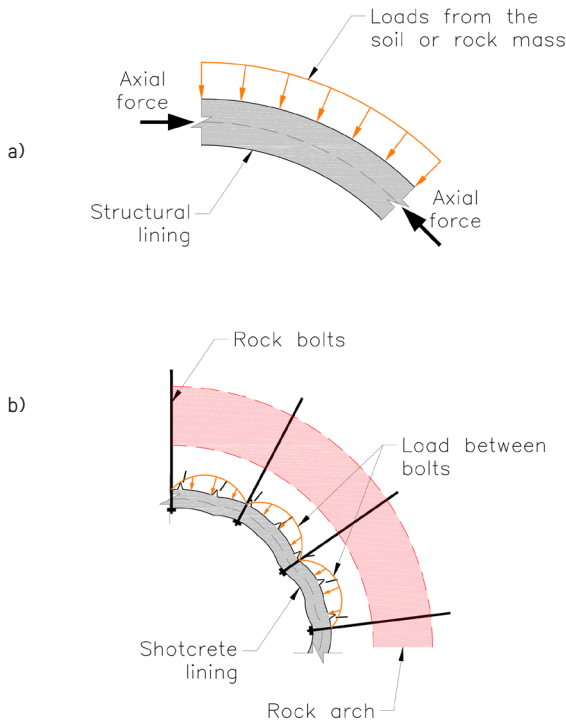


Fig 9. (a) Typical structural tunnel lining equilibrium  
(b) Typical rock tunnel support

pressures measured in the laboratory using powder swelling tests, and he mentions that the Norwegian Public Road Administration Guidelines recommend using only 30%. Steiner (1993) concludes that, in general, field swelling pressures in argillaceous rocks are significantly lower than pressures measured in the laboratory.

It is important to state that all linings designed for swelling rocks are concrete structures and not conventional rock tunnels, where tunnel support is provided by a thin shotcrete lining, combined with rock bolts. This important design decision may be explained by the following conceptual discussion: a conventional rock tunnel support consists of a thin shotcrete lining and rock bolts, which help to create a rock arch around the tunnel. The shotcrete lining does not usually have a regular geometry, no foundation and no invert, and, therefore, is not capable of supporting rock mass pressures by axial (compressive) forces. Therefore, rock loads are supported directly by the bolts and by the rock arch. The shotcrete has the goal of providing some confining pressure and supporting possibly loose rock blocks:

In the case of a structural concrete shell, considering a circular tunnel loaded uniformly, the lining loads can be estimated by:

$$N = p \times r \quad (7)$$

Where  $N$  is the axial force,  $p$  is the load on the lining and  $r$  is the radius of the tunnel. The compressive stress in the tunnel lining ( $\sigma_c$ ) can be estimated, assuming a uniform stress distribution in the lining, as follows:

$$\sigma_c = \frac{N}{A} \quad (8)$$

where  $A$  is the cross section of the lining (lining thickness).

Assuming a maximum compressive stress in the lining of 20 MPa and a typical lining thickness of 30 cm, the maximum load  $p$  (swelling pressure) is:

$$p = \frac{\sigma_c \times A}{r} = \frac{6}{r} \quad (9)$$

For a 12 m diameter tunnel, the maximum swelling pressure would be 1 MPa. This simplified approach is conservative, because it does not consider delayed lining installation, i.e., that some radial displacement may occur before the lining is installed.

Refining this simple approach using a logarithmic relation between swelling pressure and swelling strain, as suggested by Grob (1972):

$$\varepsilon = k_q \times \log \left( \frac{\sigma_z}{\sigma_0} \right) \quad (10)$$

Where  $\varepsilon$  is the swelling strain,  $k_q$  is the swelling parameter,  $\sigma_z$  is the stress at a given strain and  $\sigma_0$  is the stress for null swelling strain.

Assuming that the rock mass affected by swelling has a thickness of 2 m, which is compatible with measurements presented by John et al. (2009) and Leca et al. (2000), it is possible to estimate the displacement  $\times$  pressure relation. Figure 10 shows the displacements for a soil with maximum swelling pressure of 1 MPa and maximum swelling expansion of 10%.

For a circular tunnel under radial load, the radial displacement  $u_r$  is a function of the lining stiffness and the tunnel radius:

$$u_r = \frac{p \times r^2}{E \times A} \quad (11)$$

For a 12 m diameter tunnel, with a 30 cm thick concrete lining, with an elasticity modulus of the lining of 20 GPa, the relationship between pressure and radial displacement are represented in Figure 10. An initial displacement of 2 cm due to, for example, delayed lining installation / activation, was assumed.

Figure 10 shows that the lining is relatively stiff and, as soon as installed, will restrain displacements and take high loads. Analysis with more sophisticated numerical models will allow for a more realistic analysis, with non-circular tunnel geometries, soil-lining interaction and more sophisticated constitutive models. Nevertheless, it is clear that structural linings are capable of supporting high lining loads. Działoszyński & Stucchi (2021) present simulations in another context, but their analysis shows that conventional tunnels in soils are loaded with loads in the order of magnitude of the ones obtained in the simple model above.

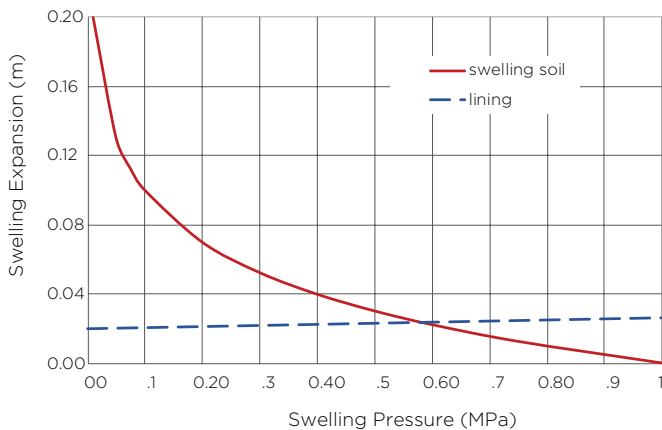


Fig 10. Lining displacement x lining load and soil expansion x swelling pressure.

When analyzing a conventional rock tunnel, usual rock bolt loads vary between 100 and 200 kN. In a simplistic approach, between 3 to 6 rock bolts per square meter would be necessary to balance a pressure of 0.6 MPa, which is not feasible.

#### 6.4 Slaking

Marinos et al. (2013) describe successful construction of 12 tunnels in molassic rock in Greece, where slaking behavior of siltstones was avoided by the immediate application of 3 to 5 cm of shotcrete. Olivier (1990) presents similar recommendations for mudrocks in South Africa.

The approach of protecting rocks that are sensitive to moisture variations seems to be a universally accepted procedure, not only in tunnel engineering, but also in other rock mechanics applications. It is, however, fundamental to make sure that the slaking behavior is not combined to swelling minerals, that may, during the design life of the structure, increase loads on the tunnel lining.

#### 6.5 Site Investigations

Several different tests are available to evaluate rock strength degradation, associated to swelling and slaking rock behavior. Almost all tests are laboratory tests and are relatively sophisticated. Therefore, a successful site investigation campaign and project need a progressive approach, starting with an initial geological assessment that includes the evaluation of literature and, where possible, other projects in the area.

If there is risk of swelling and/or slaking rocks affecting the project, a comprehensive investigation is recommended. The experience of the author, as well as in published projects, shows different tests are necessary to evaluate swelling and slaking potential, including saturated and dry UCS, ethylene-glycol immersion, Atterberg limit, SDT, axial swelling tests, preferably on undisturbed samples and rock powder and mineralogical tests, like X-ray diffraction.

Considering that site investigations usually consist of a limited number of boreholes, it is important that the site investigations continue throughout the project, testing in

situ and excavated materials, to evaluate tunnel stretches that may be affected by deleterious rock properties. To allow for this approach, it is important that the tunnel design in its entirety is sufficiently flexible to allow for the installation of variable linings, designed for specific conditions that may only be detected during tunnel excavation. Considering that in many cases the internal shape of the tunnel is defined by its use, the geometry of the tunnel should be chosen in a way that allows for the incorporation of a structural lining, including a curved invert.

## 7. CONCLUSIONS

Rock strength degradation is associated with slaking and swelling. Although some rock types are known to be associated to these phenomena, different igneous, metamorphic, and sedimentary rocks, usually considered “stable,” have also shown swelling and slaking problems associated with tunneling works.

Chemical and physical processes are associated with slaking and swelling. However, these processes are still not well described: for example, in some cases, high contents of swelling minerals do not lead to rocks with high swelling pressures. For that reason, the evaluation of different tests is necessary to assess swelling and slaking behavior.

The lack of deeper knowledge of rock behavior makes a robust design important. The design should incorporate, from the beginning, a comprehensive evaluation of geology with possible scenarios based initially on desk studies, followed by walkover, orienting an evolutive site investigation campaign, that extends into tunnel construction. Design should be flexible to accommodate different solutions for different conditions.

An inadequate design, i.e., that allows for the development of slaking and swelling mechanisms, will lead to the progressive degradation of the rock mass, with a significant risk of the rock mass becoming soil-like. In general, the reduction of access to water and providing significant confinement to the rock are adequate solutions.

It is, however, seldom necessary to design the lining for full swelling pressure obtained from laboratory tests. Several authors conclude that swelling pressures acting on tunnel linings are significantly lower than values measured in the laboratory.

It is the understanding of the author that future research is necessary, including the possibility of better previous mapping of geomechanical properties, as well as the development of constitutive models that include rock strength and deformability variations as a function of swelling strain.

## ACKNOWLEDGEMENTS

I would like to thank the ISRM Board for the honor of being chosen as Franklin Lecturer at the IX Latin American Rock Mechanics Symposium. I would also especially like to thank Prof. Luiz Guilherme de Mello, for his valuable technical review of the paper, Ms. Isabel Caram de Souza, for her editorial help and Mr. Luis Fernando da Silva Belizario, for his help with the figures. 🇧🇷

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## ROCHA MEDAL LECTURE

V.R.S. De Silva | Monash University, Australia



### ROCK FRACTURE STIMULATION USING A SLOW ENERGY RELEASING FRACTURING COMPOUND FOR PERMEABILITY ENHANCED IN-SITU LEACHING

#### ABSTRACT

Conventional mining methods are becoming increasingly uneconomical with declining ore grades. In-Situ Recovery (ISR) of minerals is one alternative technology that can be adapted to liberate minerals from low-grade permeable mineral deposits. ISR susceptibility is dependent on the permeability of the host-rock formation. Although prevailing methods such as hydraulic fracturing and explosive blasting are used for preconditioning, these methods have limitations such as excessive formation damage around well fields and uncontrolled fracture propagation. Therefore, an alternative method is proposed to initiate fractures around an injection well using a patented hydrophobic, injectable, Soundless Cracking Demolition Agent (SCDA). The fracture performance of the compound was investigated by numerically simulating the fracture initiation and propagation using the Discrete Element Method. The modified SCDA was also tested in the laboratory by fracturing multiple low-permeability sandstone specimens under hydrostatic stresses up to 20 MPa. Due to the fracturing nature of the agent, an increase in the fracture density was observed (by 116%) with increasing confining pressure (from 70 kPa to 20 MPa). Furthermore, during SCDA charging, the rock is subjected to a gradual fracturing process (10–25 hrs) facilitating safer, controlled fracture propagation, around the borehole. Finally, the fracture permeability of the specimen was calculated. Compared to the very low intact sandstone permeability ( $7.6 \times 10^{-20} \text{ m}^2$ ) an improved permeability of  $9.79 \times 10^{-13} \text{ m}^2$  at a confining pressure of 30 MPa was observed following pre-conditioning. The radial fracturing observed using this method indicates that fracture initiation with SCDA charging is a potential complementary method to improve the permeability of host-rock formations.

## 1. INTRODUCTION

### 1.1 Mining: a global outlook and an alternative approach

The ongoing global decline in ore grades has led to increased energy consumption in mineral liberation using conventional mining methods. Conventional mining accounts for over 6% of world energy consumption (Holmberg et al. 2017) and ore grades are further expected to decline in the future (Rötzer & Schmidt 2018). Despite this trend, mineral extraction is further

expected to rise with the transition to renewable energy and electric vehicles (Watari et al. 2022). As shown in Figure 1a, the embodied energy in mineral liberation shows an exponential increase with declining ore grades. The increasing waste rock volume in the mineral extraction process is the main contributor to this elevated energy expenditure. In conventional mining operations, as the host rock volume increases the subsequent processes of haulage and grinding operations (Figure 1b) result in a drastic increase in energy consumption.

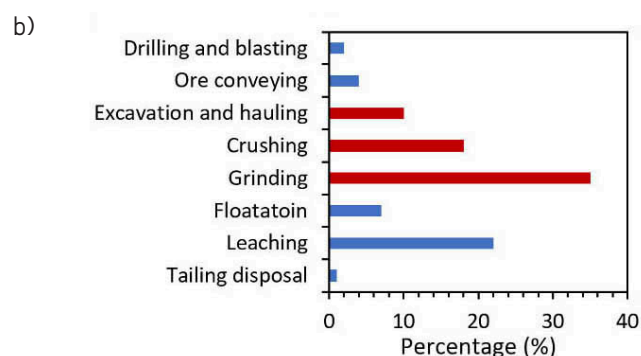
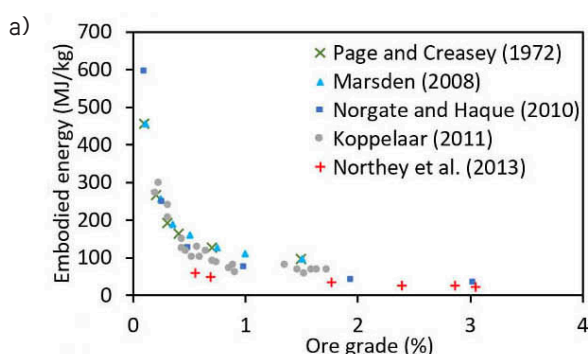


Fig 1. Energy consumption in conventional mining (a) with declining ore grade, (b) proportion of energy usage in operations (Stadler, A. & Boucaut, S. 2015)

**15** The target to limit the global temperature rise to 1.5°C by 2050 according to the Paris agreement calls for alternative mining technologies that can eliminate the current practices of energy-intensive mining operations. Furthermore, these technologies must enable the economic recovery of minerals from deposits that are below the cut-off grade for conventional mining. In-situ recovery (ISR) is an alternative, nonintrusive mining technology that may be adopted for low-grade mineral extraction. However, ISR is limited to permeable host-rock formations where a leaching solution can be easily circulated through an ore body to dissolve target

minerals. This is done by injecting a lixiviant (typically a weak acid) through a well field drilled into the target ore deposit. The mineral-rich solution is then extracted from the orebody using recovery wells (Figure 2). Typical recovery rates of minerals for ISR could range between 60- 90% (Northey et al. 2013) depending on the host-rock formation and mineralogy. Compared to conventional methods of mining, ISR is less intrusive and requires only the injection and extraction wells to be formed on-site leading to a lower operation footprint. Thus, ISR could in theory eliminate excavating, hauling, crushing, and grinding operations that account for over

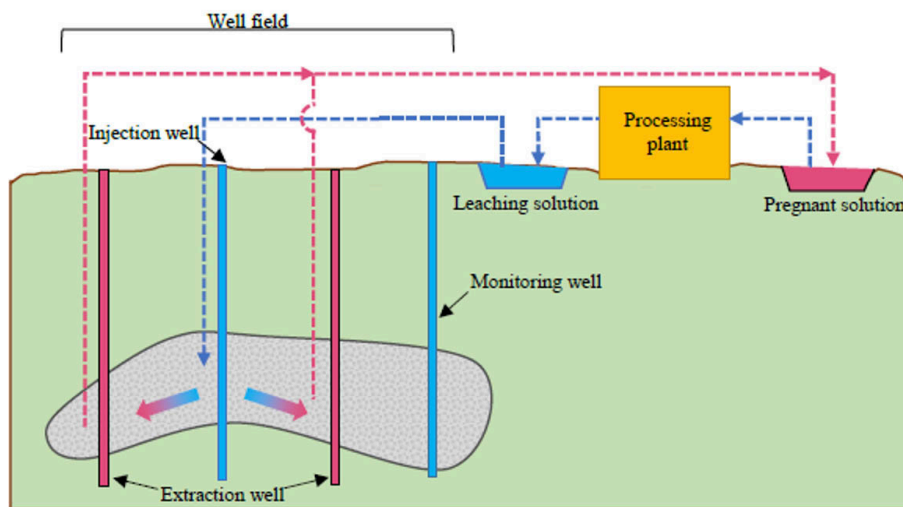


Fig 2. Schematic diagram of the ISR process

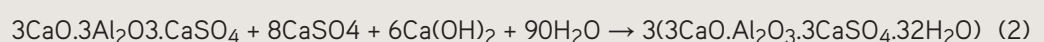
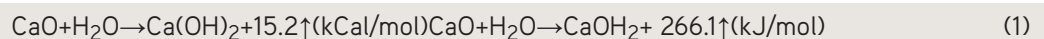
60 % of the total energy expenditure of conventional mining (Figure 1b).

However, the efficiency of ISR is reliant on the permeability of the host rock and at present ISR is limited to previous ore bodies. Application of ISR in impervious host rocks requires permeability enhancement by artificial fracture stimulation. Current practices for fracture stimulation include blasting (McCarter 1996) and hydraulic fracturing (He et al. 2016). However, both these methods have characteristics, which are detrimental to the ISR process. Blasting produces localized fractures that are difficult to control with large variability of fragment size (Saharan et al. 2006). On the other hand, hydraulic fracturing mainly generates a single uncontrolled fracture, the direction of which is dictated by the in-situ stress anisotropy. This is suboptimal for ISR as the risk of groundwater contamination from the leaching solution increases if the preconditioning is uncontrolled. From an environmental point of view, hydraulic fracturing requires a large amount of fracturing fluid, which could potentially leak

off to surrounding aquifers from uncontrolled fracture initiation. Therefore, any artificial fracture stimulation method for enhanced ISR must be able to initiate a controllable and localized fracture network in the host rock.

## 1.2 Pre-conditioning using Soundless Cracking Demolition Agents

SCDA also known as soundless cracking agents, expansive demolition agents, and non-explosive demolition agents is a cementitious powdery substance predominantly consisting of Calcium oxide and other cementing materials. When hydrated, an injectable slurry is produced that overtime solidifies and expands volumetrically through the formation of Calcium Hydroxide (Eq. 1) and Ettringite (Eq. 2). When this crystal growth is restrained inside a borehole it exerts an outward thrusting pressure known as crystal growth pressure  $\Delta P$ , given by  $\Delta P = RT/V_m \ln(a_s/a_o)$ , where  $V_m$  is the molar volume of the  $\text{Ca(OH)}_2$  crystal,  $R$  is the gas constant,  $T$  is the absolute temperature,  $a_s$  and  $a_o$  are the mean activity of the supersaturated and saturated





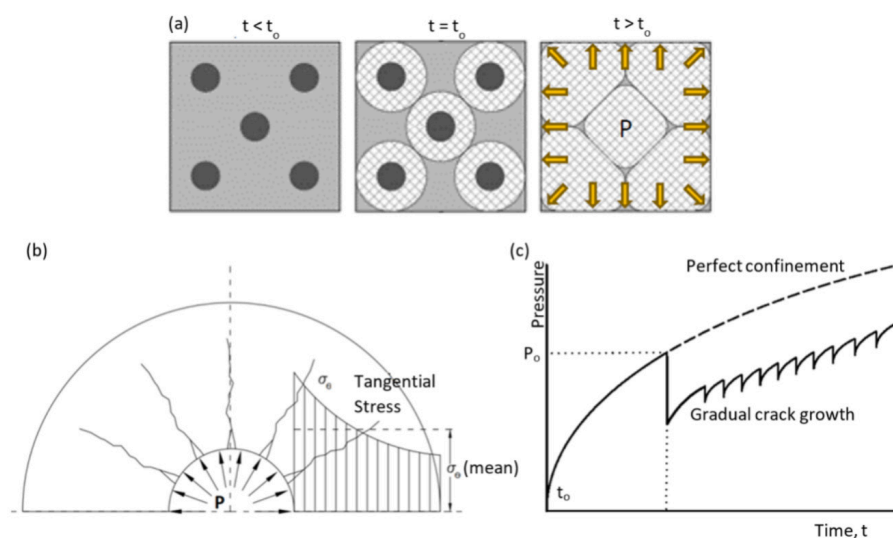


Fig 3. SCDA charged crack propagation (a) the spherical expansion model (b) crack propagation from the borehole, (c) Expansive pressure development in the borehole during crack growth

solutions in the aqueous slurry respectively. As indicated in Figure 3a, this expansion is explained by the Spherical expansion model for  $\text{Ca}(\text{OH})_2$ , where an expansive pressure is exerted in the surrounding body when the volumetric expansion of  $\text{Ca}(\text{OH})_2$  is restrained (Ish-Shalom & Bentur, 1975).

During the fracturing process, SCDA is first mixed with water (30 % by weight of SCDA) to form a slurry and injected into the pre-drilled holes in the rock. The subsequent exothermic reaction allows the material to volumetrically expand over several hours. Under the confinement in a borehole, the volumetric expansion generates an expansive pressure and initiates fractures around the borehole when it exceeds the tensile strength of the rock (Laefer et al. 2010) (Figure 3b). SCDA charging inside a borehole induces a radial compressive stress field and tangential tensile stress around the injection well. The initiation of a fracture indicates a release of confinement of the rock and a resulting drop in expansive pressure can be observed. The idealized pressure plot in Figure 3c shows that the tensile strength of the rock is exceeded at expansive pressure  $P_0$  and the first crack is initiated by SCDA expansion. The fracture is only propagated when the tensile stress is further increased by SCDA expansion. The slow energy-releasing mechanism and the corresponding controlled fracture initiation and growth mean that stable and quasi-static crack growth can be maintained during the fracturing process.

The application of SCDA has been limited due to the inability of SCDA to fracture rock in underwater conditions and its slow expansive pressure generation. This is because, in its slurry form, SCDA completely disintegrates in water. This study presents a patented modified SCDA that can be used for subsurface rock pre-conditioning under submerged conditions, with a

particular focus on ISR. Next, the fracturing potential of the modified SCDA is investigated both experimentally and numerically. Finally, the fracturing potential and the resultant permeability improvement of SCDA are compared against hydraulic fracturing under laboratory conditions.

## 2. A MODIFIED SCDA FOR ROCK PRE-CONDITIONING

Considering the existing limitations of SCDA in subsurface applications, it was modified to enhance hydrophobicity and fluidity in SCDA. This was achieved in a three-step process involving the precise inclusion of three additives to SCDA. 1) A viscosifier (VEA- Viscosity enhancing agent) in the form of welan gum, which is an anionic exopolysaccharide that introduces hydrophobic properties to SCDA. 2) A high-range water reducer (HRWR) in the form of Sodium naphthalene formaldehyde sulphonate (SNSF) to increase the fluidity of SCDA without increasing the water content. 3) A chemical accelerator in the form of anhydrous calcium chloride ( $\text{CaCl}_2$ ) to alter/increase the reaction rate of SCDA.

Welan gum is a long-chained biopolymer produced by a controlled submerged fermentation using *Alcaligenes ATCC 31555* microorganism species (Kaur et al., 2014). It adheres to water molecules in the slurry and intertwines with adjacent molecules (Figure 4a). At sufficiently high concentrations, the adsorption of welan gum to SCDA particles increases the hydrophobicity of the material. Adding 0.15% (w/w) welan gum to the mixing water was sufficient to decrease the washout mass loss of SCDA from 36% to 2% (improve hydrophobicity). The washout mass loss in this instance is the measurement of the reduction of SCDA mass after multiple immersions in a column of water. The adsorption of carboxyl ( $-\text{COOH}$ ) and hydroxyl ( $-\text{OH}$ ) groups in welan gum to SCDA particles decelerate the onset of expansive pressure by 400 % (Figure 4b) and the intertwining of molecules reduces the fluidity of SCDA by 60 % (Figure 4c). The

15 fluidity degradation of SCDA was mitigated with the addition of HRWR (by 1 % to 2 %). SNSF, in the mixing water solution, separates into  $\text{Na}^+$  and Naphthalene Sulfonate Formaldehyde (SNF) condensate that is negatively charged. The hydroxyl groups in SNF adsorb to SCDA particles and create electrostatic repulsion forces between particles that maintain the fluidity in the SCDA slurry. The retardation caused by welan gum was adjusted by adding anhydrous calcium chloride (by 1 % - 2 %), which increased the reaction rate of SCDA without altering the hydration products. The  $\text{Cl}^-$  ions introduced by  $\text{CaCl}_2$  accelerate the reaction rate by creating voids in the Calcium Silicate Hydrate (CSH) gel diffusion barrier providing access for water molecules to unhydrated SCDA particles in the system (Figure 4d). Consequently,

this reaction produces smaller clusters of hydrated products (Fig.3e) allowing more free water to permeate into unhydrated SCDA particles.

The final composition of 2%  $\text{CaCl}_2$ , 0.1% VEA, and 2.5% of HRWR with 30% of water by weight of SCDA was found to produce a superior SCDA having a 79% improvement in washout resistance and a 44% improvement in the expansive pressure generation rate compared to the base SCDA. A performance comparison between a generic SCDA and its modified counterpart is shown in Table 1. This new fracturing compound shows the potential to be used in the subsurface, and submerged conditions for rock fracture stimulation in various engineering applications including permeability-enhanced ISL.

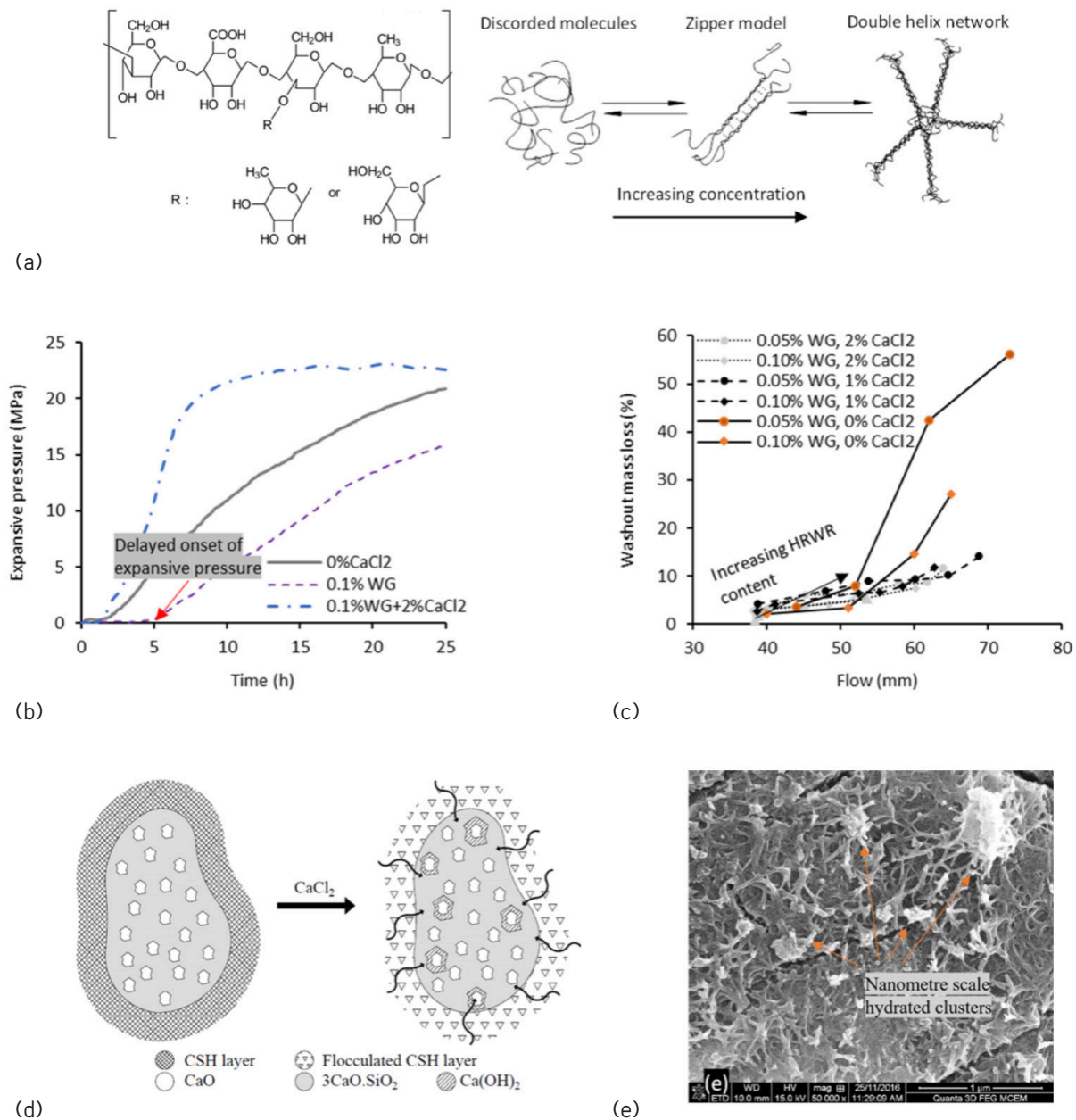


Fig. 4 Modification of SCDA (a) welan gum molecular structure and intertwinement, (b) SCDA expansive pressure comparison, (c) SCDA fluidity/flow (mini-slump cone spread) and hydrophobicity (washout mass loss) comparison, (d) effects of  $\text{CaCl}_2$  in SCDA hydration, and (e) SEM micrograph of  $\text{CaCl}_2$  induced nano-scale hydration clusters, WG – welan gum (De Silva et al., 2019)

Table 1. Comparison of generic and modified SCDA

SCDA type	Generic	Modified	Improvement over generic SCDA (%)
Washout mass loss (%)	35.67	7.49	79.00
Flow (mm)*	68.12	60.11	-11.76
Onset of expansive pressure (hr)	2.00	0.96	52.00
Expansive pressure after 5 hrs of hydration (MPa)	4.97	12.32	147.89
Initial rate of expansive pressure development (MPa/hr)	1.50	2.17	44.67

Dissolution in water



\* Flow calculated using the mini slump cone test (De Silva et al., 2017)

### 3. NUMERICAL SIMULATION OF SCDA CHARGED FRACTURE PROPAGATION

After modifying SCDA for host rock preconditioning deep saturated host-rock formations, its fracturing performance was evaluated using the Discrete Element Method. The numerical simulations were performed using the general-purpose discrete element modelling software, particle flow code 3D (PFC3D 5.0 by ITASCA). The numerical tool was developed to predict and accurately capture the fracturing process during SCDA charging.

#### 3.1 The numerical grain assembly

The laboratory fracturing tests were performed on homogenous coarse-grained silicate cemented Hawkesbury sandstone, obtained from the Sydney basin in Australia. Prior to SCDA-charged fracture simulations, a numerical rock mass was assembled in PFC3D using the flat-jointed contact model (Itasca, 2014). The numerical rock mass was assembled by packing spherical particles in a vessel to a predetermined porosity and density using the grain scaling method under zero friction, which iteratively scales the grain size to allow dense packing of particles in a vessel. Once the desired porosity of the numerical rock mass is achieved, the intergranular contact properties were assigned to particles in the assembly. The flat-jointed

model was used to create the inter-particle bonds of the model. Multiple interface elements in the flat jointed model allow partial damage to the bond and are capable of resisting moments at the bond contact. The bonded assembly was then calibrated using laboratory test results for Uniaxial Compressive Strength (UCS). Afterwards, the model was validated against Brazilian disk Tensile Strength tests (BTS). A comparison between the experimental results and the numerical simulations for the mechanical strength tests of the specimens and the calibration parameters of the flat jointed model are shown in Table 2.

#### 3.2 SCDA charged fracture simulation

Following the micro-mechanical damage simulation in the numerical rock mass assembly, the model was used to simulate SCDA charging. A cylindrical numerical rock assembly with 18064 bonded spherical particles (2.5mm - 3.0mm dia.) was produced by packing in a vessel (54 mm diameter and 108 mm height). A 5mm diameter injection well was simulated in the centre of the cylinder and the particles around the injection well were scaled by a factor of 0.6 to minimize the size effect on fracture initiation. The expansion caused by SCDA in the injection well was simulated using a servo-controlled rigid cylinder where the wall diameter of the

Table 2. Comparison of experimental and numerical strength results

Micromechanical properties	Calibration results				
Parameters	Value	Parameter	Experiment	Numerical	Error %
Bonded contact E. modulus, $\bar{E}$ (GPa)	5.9	UCS (MPa)	61.97	63.80	2.95
Bonded contact k-ratio ( $k_n/k_s$ )	0.86	E mod. (GPa)	7.77	7.85	1.03
Bonded contact Tensile strength (MPa)	5.0	Strain at failure	0.0084	0.0086	2.38
Bonded contact cohesion, C (MPa)	21.0	BTS (MPa)	3.94	3.89	1.27
Bonded contact friction angle, $\phi$ (°)	40				
Interface elements, on contact	3				
Unbonded contact E. modulus (GPa)	1.5				
Unbonded contact k-ratio ( $k_n/k_s$ )	3.0				
Unbonded contact friction coefficient, $\mu$	0.1				



15 cylinder was set to increase radially. The expansive pressure generated within the borehole was measured by dividing the sum of contact forces acting on the inner wall by the contact area of the borehole. The top and bottom flat plates, and the outer walls of the vessel were also servo controlled where wall velocities were controlled to apply a constant stress acting on the particle assembly. This method of simulation allowed the expansive pressure developed within an injection hole to be monitored with fracture propagation as shown in Figure 4. Experimentally observed fracture propagation obtained from intermittently scanning the specimen during the fracturing process using X-Ray computed tomography (X-Ray CT) at the Australian Synchrotron imaging and medical beamline is also shown in Figure 5 for comparison.

#### 4. SCDA CHARGING UNDER ISOTROPIC CONFINEMENT

##### 4.1 The effect of confining pressure

Following the preconditioning numerical simulations using SCDA, fracturing experiments were performed to assess the effects of lateral confinement on fracture performance. The lateral restraint against crack growth provided by large confining pressures results in the development of higher peak expansive pressures with increasing confinement. Furthermore, with increasing confining pressure, the failure mode of the specimen transitions from a tensile to a mixed tensile and shear failure. This is due to the confining pressure increase around the borehole. The stress state changes from

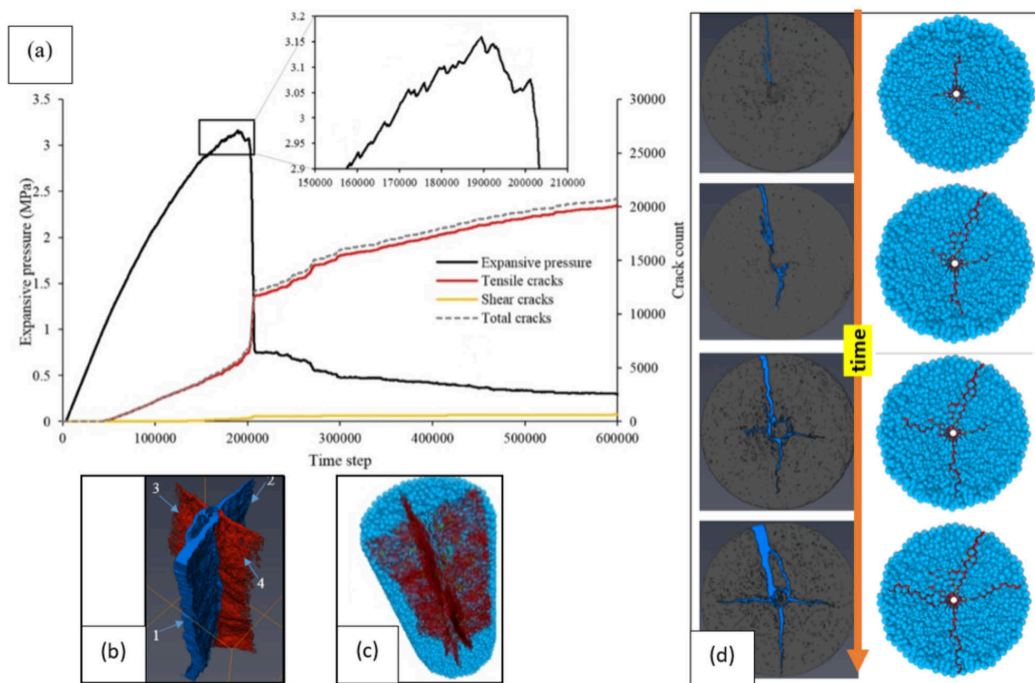


Fig 5. (a) Expansive pressure development in the injection well with fracture propagation, final fracture pattern of the rock specimen

(b) CT reconstruction, (c) numerical simulation, and (d) fracture evolution during SCDA charging, experimental (left) and numerical (right).

The expansive pressure variation within the borehole under zero confinement is shown in Figure 5a. The expansive pressure development within the borehole could be idealized as a staggered pattern (minor pressure drops) due to the stress release during fracture propagation around the pressurized borehole (Dowding and Labuz, 1983) (Figure 3c), which was accurately captured in the model at peak expansive pressure (Figure 5a). As the expansive pressure increased, the tensile stress in the vicinity of the borehole increased and resulted in radial fracture propagation. Consequently, the fractures under zero confinement were predominantly tensile as shown in Figure 5a. As shown in Figure 5d, the fractures propagate to the edge of the specimen leading to an abrupt drop in the expansive pressure causing the specimen to split.

a tangential tensile stress dominant state around the injection well at zero confinement to a stress state dominated by radial compressive stress state as the confining pressure increases. The tensile stresses are caused by the expansive pressure generated within the borehole, and the compressive stresses increase with the confining pressure. The reduced extent of the tensile stress field around the injection well due to the increase in confining pressure leads to a greater resistance for crack growth. Therefore, the strain energy from SCDA charging is released in the rock mass by initiating additional fractures around the borehole as opposed to crack growth. A more detailed description of the confining pressure effect on SCDA expansion is provided by De Silva et al. 2018.

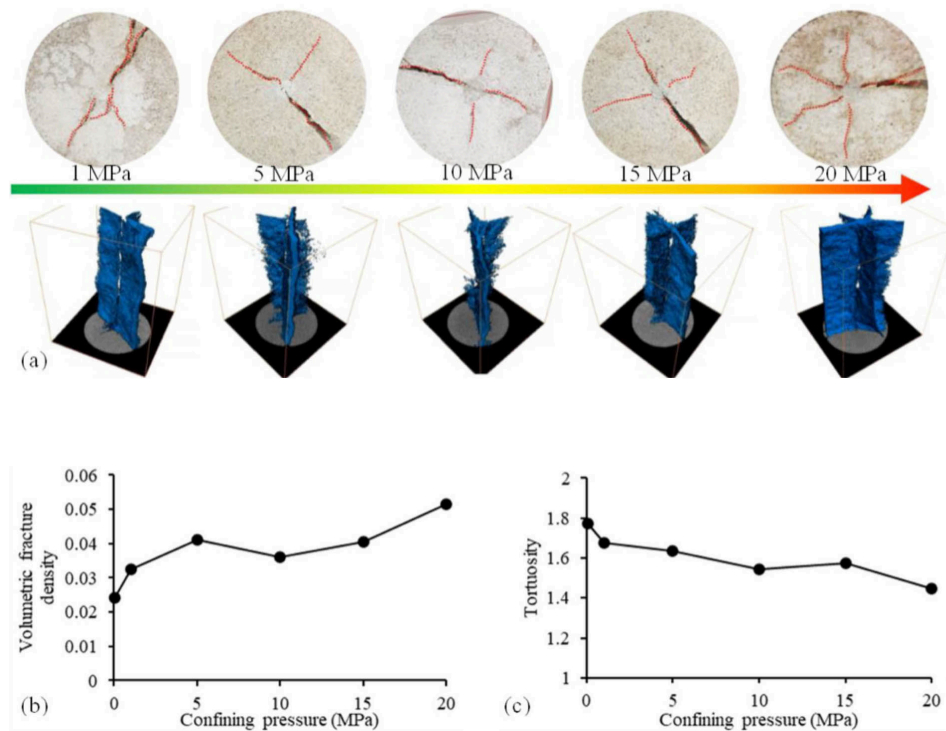


Fig 6. SCDA charged fracturing (a) top view of fractured specimens and CT reconstruction of produced fractures with increasing confining pressure, (b) fracture density and (c) tortuosity

The fracture patterns observed for specimens fractured under different confining pressures are shown in Figure 6a. As discussed, the experimental fracture observations indicate an increase in the fracture density and a decrease in the fracture tortuosity around the injection well with increasing confining pressure (Figures 6 b and c).

#### 4.2 A comparison between hydraulic fracturing and SCDA charging

The fracturing performance of SCDA was evaluated against hydraulic fracturing in the laboratory by considering the number of fractures initiated around an injection well. Two identical specimens (54 mm dia. and 108 mm height) were fractured in the laboratory using hydraulic fracturing and SCDA charging. The isolated fracture network details of each of the specimens obtained by CT scanning following the fracturing experiments are shown in Figure 7 and Table 2. The fracture growth direction in hydraulic fracturing is dictated by the rock mass heterogeneity and stress anisotropy. This was evident in the experimental observations. First, the fracture initiated parallel to the injection well (in the direction of the major principal stress) and then branched out perpendicular to the initial direction in a plane parallel to the bedding layers of the specimen (Figure 7a). Consequently, a continuous fracture spanning across the entire length of the specimen was not attainable. Fracture propagation in toughness-dominant hydraulic fracturing results when the fluid pressure at the crack tip exceeds the toughness of the rock. When a weaker plane such as bedding layers exists in the fracture path, the fractures tend to propagate in the direction of the weaker plane (Hossain

et al. 2000) and result in fluid leak off preventing further crack propagation. Although horizontal fracture propagation is unlikely due to the stress conditions in this experiment, the presence of faults or weaker planes (bedding in this case) altered the direction of fracturing.

On the other hand, SCDA charging introduces multiple radial fractures initiating from the borehole irrespective of material heterogeneity due to the nature of pressure exertion described in section 1.2. Four major fractures were identified in the SCDA charged specimen. Out of the four fractures in the SCDA charged specimen, fracture 1 and 2 are continuous fractures and fracture 3 and 4 are connected fractures spanning the entire length of the specimen.

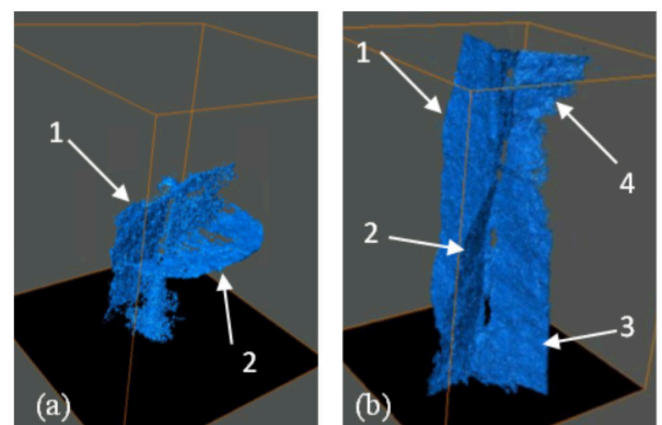


Fig 7. Fracture networks (a) hydraulic fracturing, and (b) SCDA charging

**15** Table 3: Details of Hydraulic fracture and SCDA charged fracture

		HF	SCDA
Fracture volume fraction		0.006	0.061
Tortuosity		5.83	1.26
Avg. fracture length (mm)	1	30.6	108
	2	23.73	108
	3	-	78.67
	4	-	29.33

## 5. FRACTURE PERMEABILITY

Due to the nature of the hydraulic fracture in the experiment (Figure 8), the specimen permeability was dictated by the rock matrix permeability of  $7.6 \times 10^{-20} \text{ m}^2$  (a flow rate of  $3.2 \times 10^{-4} \text{ ml/s}$ ) for water at the confinement of 30 MPa and an injection pressure of 6 MPa. Figure 8 shows the steady-state flow rate variation with injection pressure at different confining pressures ( $\sigma_3$ ) for the SCDA charged specimen. The cubic law was used to calculate an average hydraulic aperture for the fracture flow in the SCDA charged specimen and a non-linear correlation was observed for the steady-state flow rates and the injection pressures.

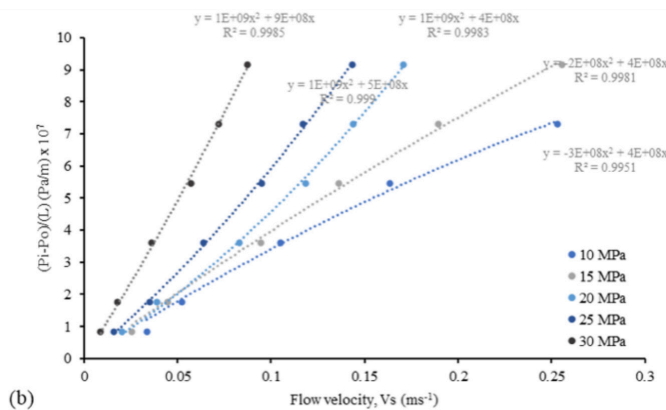
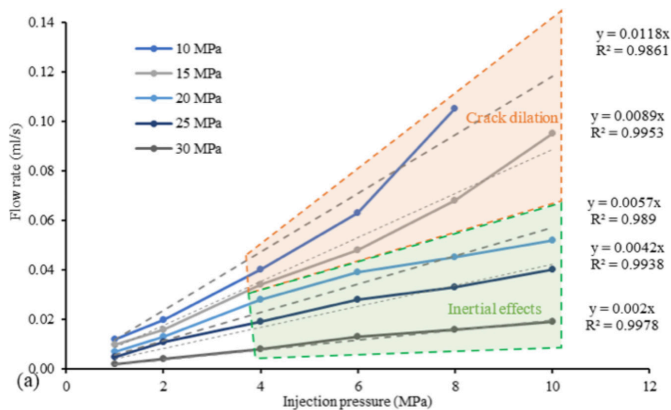


Fig. 8 Fracture flow permeability in SCDA charged specimen. (a) flow rate variation with injection pressure and (b) pressure gradient with flow velocity

Figure 8b shows the variation of the pressure gradient across the SCDA charged specimen with flow velocity, which is represented by second-order polynomials. It must be noted that the Polynomial regressions shown in Figure 7b for confining pressures 20 MPa, 25 MPa, and 30 MPa exhibit a disproportional increase in the pressure gradient for each increment of flow velocity. This is indicative of energy losses in the fluid flow due to inertial and turbulent effects caused by the large fracture apertures of SCDA charged specimens. Therefore, Forchheimer's equation (Eq. 3) was used to describe this flow behaviour and calculate the Darcian and the non-Darcian permeability components of the fluid flow in the SCDA charged fracture at the higher confining pressures (20 – 30 MPa).

$$(P_i - P_o) / L = \mu/k_1 \cdot v_s + \rho/k_2 \cdot v_s^2 \quad (3)$$

In Equation 3,  $P_i$  and  $P_o$  are the inlet and outlet pressures of the specimen,  $L$  is the fracture length,  $v_s$  is the fluid velocity,  $\mu$  is the fluid viscosity, and  $\rho$  is the fluid density.  $k_1$  and  $k_2$  are termed as Darcian and non-Darcian permeabilities of the material. Here, the  $\mu/k_1 \cdot v_s$  component represents the frictional flow resistance between fluid layers and the  $\rho/k_2 \cdot v_s^2$  component represents the inertial and turbulence contributions (Innocentini et al., 1999).

At lower confining pressures the opposite was true where a disproportional increase of flow velocity was observed for each increment of the injection pressure gradient. At low confining pressures (10 – 15 MPa) and high injection pressures (6 – 10 MPa), the non-linearity between the flow rate and the injection pressure indicates a possible crack dilation as a result of the low effective stresses caused by the high injection pressures. Crack dilation for the test series was observed for effective stresses lower than  $0.6\sigma_3$ .

$k_1$  and  $k_2$  in Eq. 3 for the high confining pressure conditions were calculated from the polynomial regressions shown in Figure 7b. The experimental results indicate, that SCDA charging improves the specimen permeability from  $7.6 \times 10^{-20} \text{ m}^2$  ( $7.7e^{-5} \text{ mD}$ ) intact rock matrix permeability to a fracture flow permeability of  $9.79 \times 10^{-13} \text{ m}^2$  (992 mD) at 30 MPa confining pressure.



## 6. CONCLUSIONS

This paper presents a new technology for host-rock preconditioning in In-Situ Leaching mining applications using Soundless Cracking Demolition Agents (SCDAs). First, the study involves the development of a patented (US Patent No. 10836955) hydrophobic slow energy releasing SCDA which can be used for rock fracture initiation applications under submerged conditions. Next, a DEM-based numerical model is presented to simulate the slow energy releasing fracturing process of SCDA that was used to understand the underlying mechanics of SCDA charging. Following the numerical model development, a series of laboratory experiments were carried out to investigate the fracturing performance of SCDA under different confining pressures. Finally, the fracturing performance near the injection well and the resultant permeability improvement following SCDA charging was investigated and compared against hydraulic fracturing in a series of laboratory experiments. Based on the results of this study the following key conclusions can be drawn.

- The patented SCDA improves hydrophobicity by 79 % compared to generic SCDAs and the onset of expansive pressure development is improved by 52 %. The expansive pressure development rate is further improved by 45 %. This allows SCDA to be pumped into deep geological formations and initiate controlled fractures.
- The DEM numerical model successfully simulates the expansive pressure development inside an SCDA-injected borehole and the subsequent radial fracture propagation, which were validated by experimental studies.
- Increasing the confining pressure of the surrounding rock causes the SCDA fracturing mode to transition from tensile to shear dominant mixed tensile-shear failure mode. Laboratory experiments conducted on specimens under large confining pressures (up to 20 MPa) indicate SCDA chagrining produces multiple radial fractures around an injection well.
- Compared to fracture stimulation using pure hydrofracking at the near vicinity of the injection well, SCDA charging creates multi-directional fractures around an injection well independent of rock mass heterogeneity.

## ACKNOWLEDGEMENTS

The PhD supervision of Prof. Ranjith Pathegama Gamage was instrumental to the outcomes presented in this research. The support offered by Monash University Civil Engineering Laboratory staff, the Monash Centre of Electron Microscopy (MCEM), the Monash X-Ray Platform, and the Australian Synchrotron for the experiments conducted in this research are also acknowledged. 📧

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## 16 JOHN HUDSON ROCK ENGINEERING AWARD

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### STUDY OF THE EFFECT OF COUPLED SEEPAGE AND ELASTIC/PLASTIC ROCK MASS RESPONSE AFTER IMPOUNDMENT AT THE BAIHETAN DAM

#### 1. CONTEXT

Contractional valley deformation is quite specific to high dams with heights greater than 200 m constructed in the southwest of China (Figure 1).

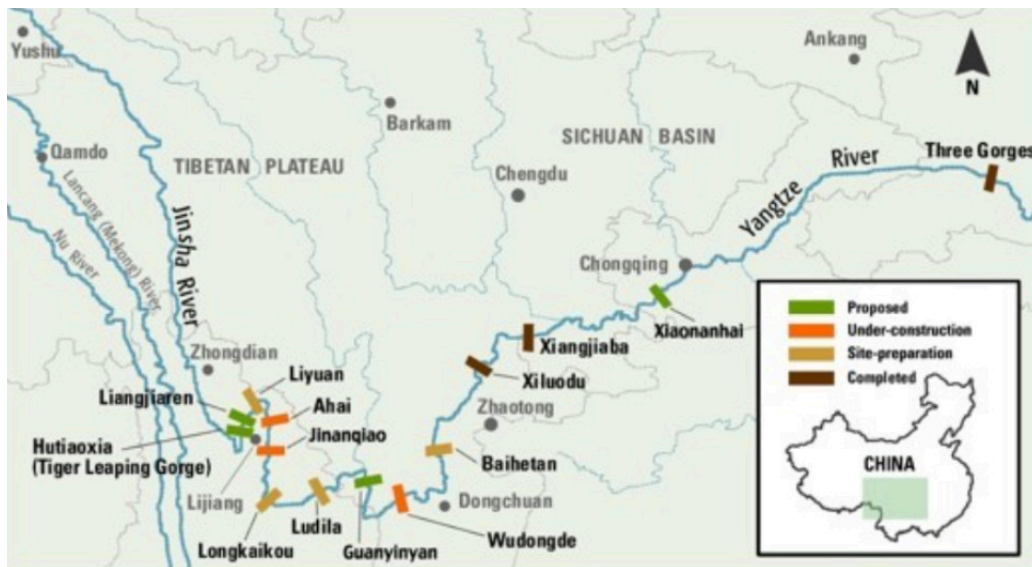


Fig 1. Map of Yangtze River valley showing location of main dams

Numerical simulations with coupling of stress and large-scale seepage were performed to study the mechanisms of valley deformation after impoundment and to determine whether and when a similar mechanism could develop at the Baihetan arch dam site — a very large structure, second only in size to the Three Gorges Dam.

Construction of the hydropower station started officially in late October 2010. The double curvature concrete dam is 289 m high. The reservoir storage capacity is 20.6 billion m<sup>3</sup> (Figure 2).



Fig 2. Baihetan arch dam — under construction



## 2. BASIC PORO-ELASTIC MECHANISMS

The initial generic 2D analyses show that two basic poro-elastic mechanisms develop after dam impoundment: a short-term “Mattress Effect” caused by the added water load (noting that pushing on a mattress causes nearby points to move downward and inward); and a time-dependent “Swelling effect” associated with seepage (the development of a fluid pressure bulb under the valley causes upward and outward movement). These opposing behaviors (corresponding to undrained and drained response) are illustrated in Figures 3 and 4.

The dominant Mattress effect manifests itself by a valley convergence at high elevations, together with valley expansion at low depth, below the impoundment water level. Both mechanisms are represented in Figure 3. The Swelling effect (caused by an increase of pore pressure during seepage) generates displacements that are opposite to those of the Mattress effect (caused by mechanical loading of the standing water) in the simulations. The magnitude of the poro-elastic displacements induced by seepage are typically significantly smaller than those generated by the pressure from the standing water in the valley. The 2D poro-elastic simulations showed that, with the two effects combined, valley convergence was higher at higher elevations and larger in the short term after impoundment.

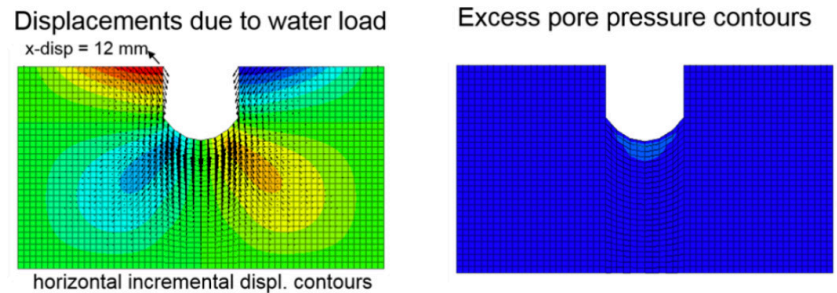


Fig 3. Illustration of 2D mattress effect

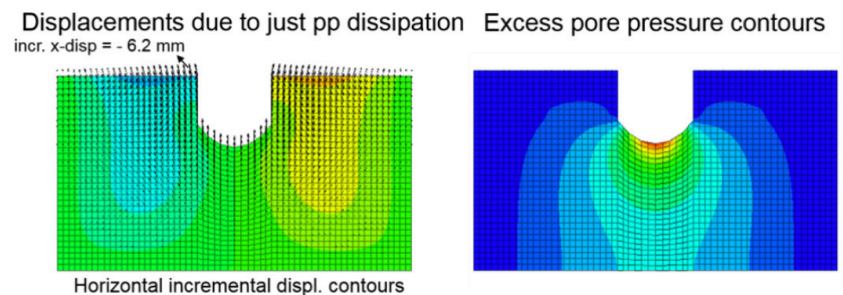


Fig 4. Illustration of 2D swelling effect

## 3. PRELIMINARY 3D SEEPAGE ANALYSIS

The steady-state excess water pressure contours caused by impoundment in a simplified 3D model of the valley and dam are shown in Figure 5.

The 3D simulation shows that a 2D behavior, like that predicted in Figure 4, develops upstream, away from the dam, and that a 3D behavior is expressed under and around the dam in the valley banks.

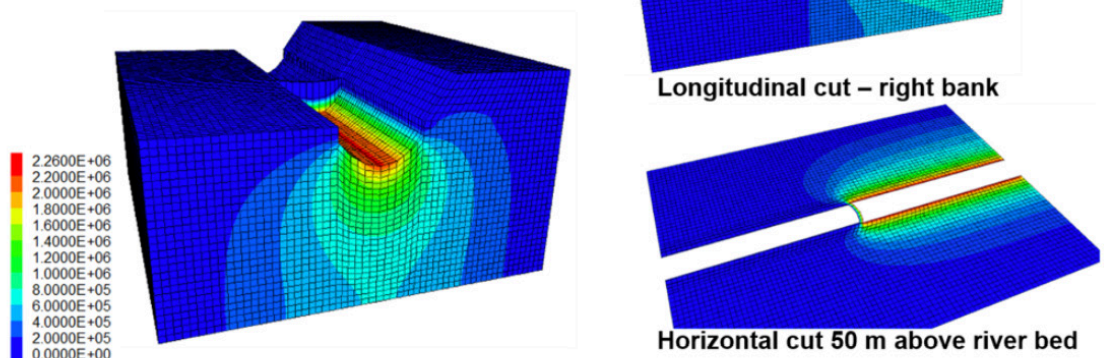


Fig 5. Illustration of 3D long-time excess water pressure from impoundment



## 16 4. COMPREHENSIVE MODEL OF BAIHETAN DAM SITE

The large-scale elasto-plastic model (4 km by 3 km by 3 km) included significant faults, drainage structures, and regions of complex rock mass response comprising columnar basalt (Figure 6).

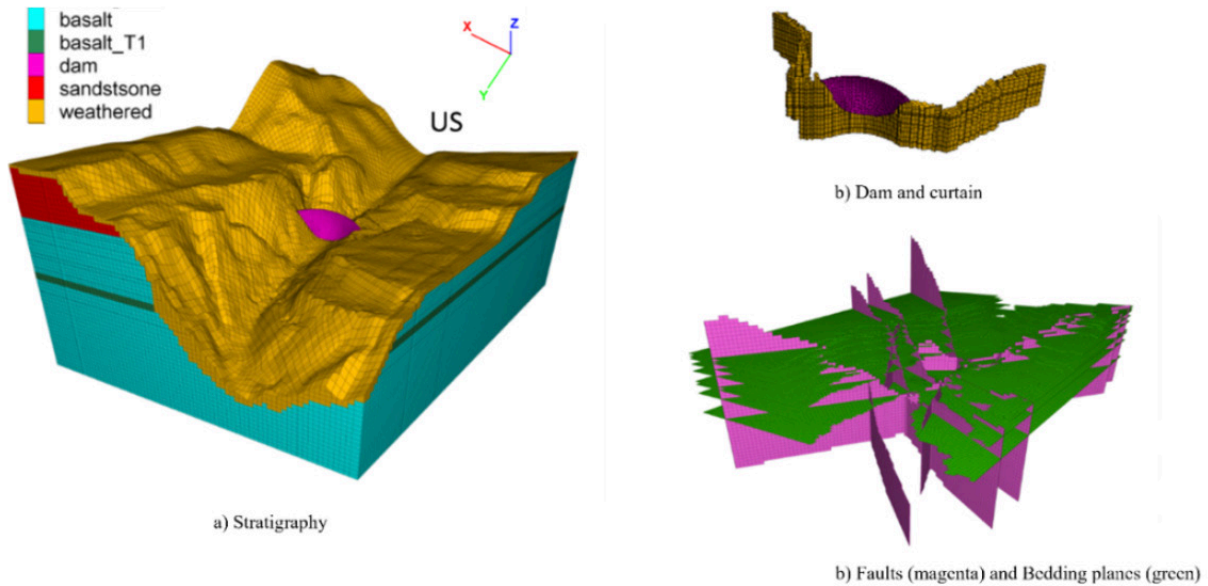


Fig 6. FLAC3D model for the analysis with stratigraphy, structure, and curtain.

Part of the project was to develop a constitutive model for the basalt, using up to four ubiquitous joint sets, which extended the state of the art in modeling such a rock mass. The response of this model (called Comba) matched very well that of samples simulated explicitly with assemblies of discrete blocks representing the basalt columns (Figure 7).

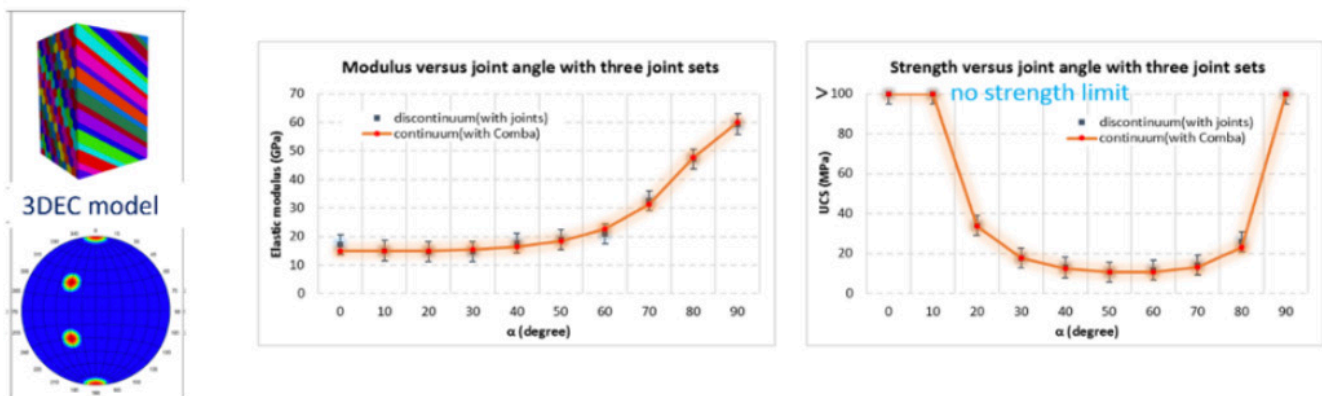


Fig 7. Element test responses: comparison between discrete (with joints) and continuum (with the Comba model).

The overall conservative predictions of rock displacements (both upstream and downstream) resulting from reservoir impoundment are shown in Figure 8. Below the dam crest elevation, the model predicts valley expansion upstream from the dam and valley convergence downstream. Downstream, the model indicates a sliding mechanism towards the valley on the left bank and superficial toppling at high elevations on the right bank.

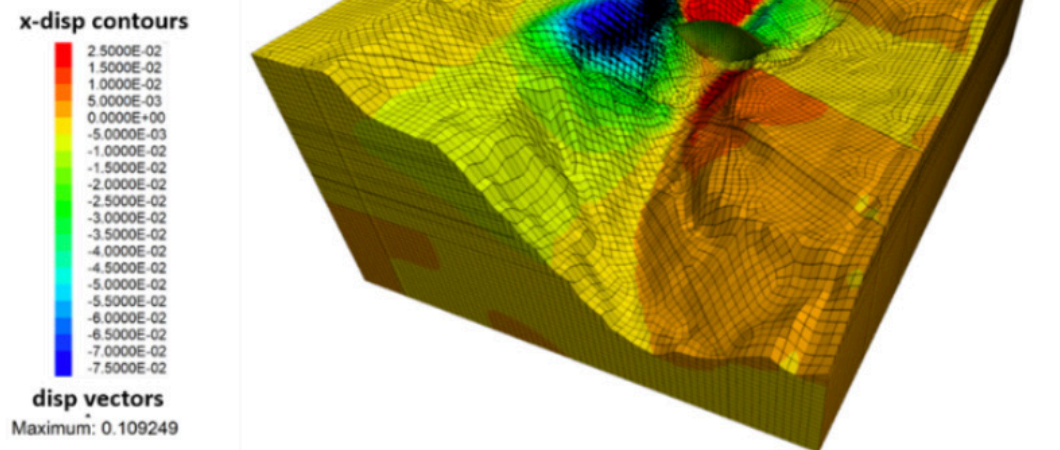


Fig 8. Contours of x-displacements at 5 years after the start of impoundment.

The mechanisms of valley deformation are illustrated further in the map view presented in Figure 9.

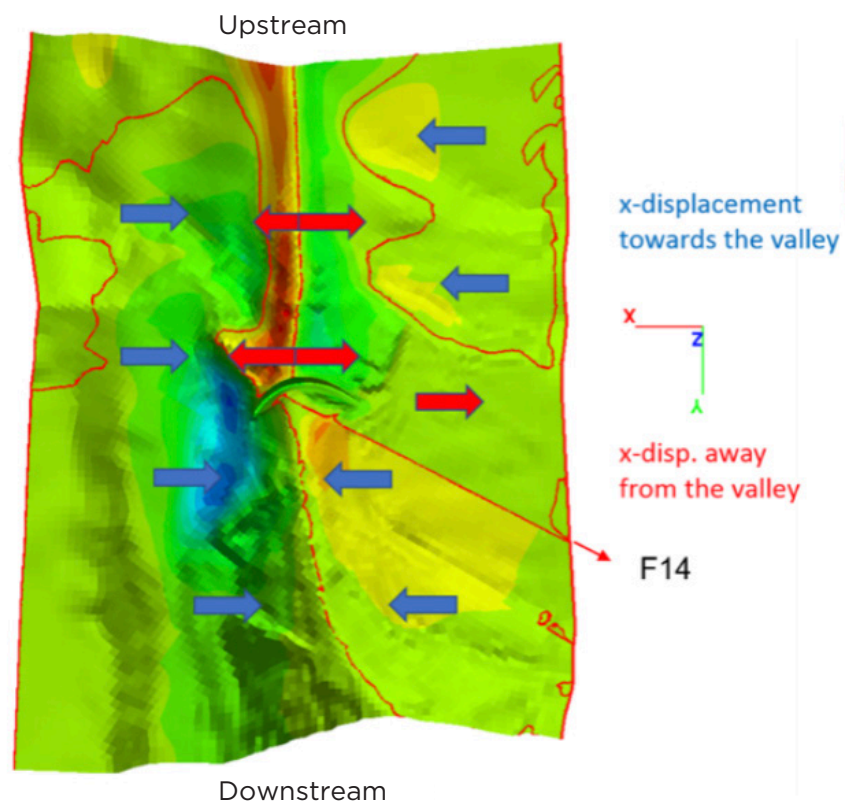


Fig 9. Map view of x-displacement contours and red iso-surface of zero x-displacement at 5 years

- 16 The Mattress effect with valley divergence below the water table and valley convergence at high altitude is revealed upstream of the dam. The valley convergence predicted downstream of the dam is attributed to slip along major discontinuities (fault and bedding plane) induced by the increase of water pressure due to seepage from impoundment.

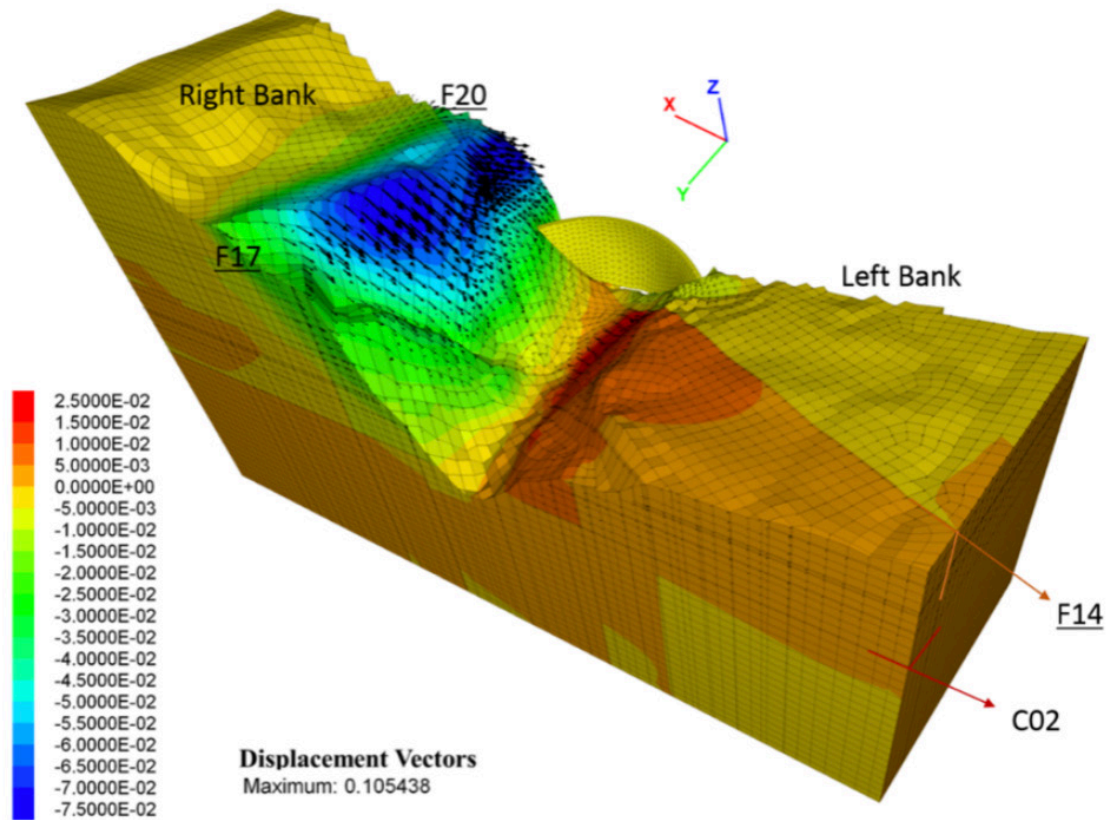


Fig 10. Displacement contours and displacement vectors in dam vicinity at 5 years

The combination of a sliding mechanism controlled by the main faults and bedding planes on the left bank along with a superficial toppling mechanism on the right bank are attributed to the fact that the bedding planes are sloping towards the valley on the left bank and into the slope on the right bank.

The model prediction along measuring lines across the valley showed that the main deformation occurred during the changes of impoundment upstream, and at some distance (of the same order as the dam width) downstream from the dam. Continuous deformation was also observed at constant impoundment level downstream of the dam. This could be attributed to the seepage effect from impoundment in the valley banks.

## 5. MODEL TAKEAWAY

Two main potential deformation mechanisms were identified in the simulations. The first is the poro-elastic Mattress effect that induces valley deformation during changes of impoundment. The second, governed by slip along major discontinuities, is caused by changes in water pressure due to seepage around the dam that also occurs at constant impoundment level.

A comparison of valley convergence prediction and field monitoring along measuring lines (available in the first 70 days after the start of impoundment) showed similar trends: a decrease in convergence when impoundment increases (caused by stress relaxation in the riverbanks); and an increase in convergence at constant impoundment level.

Further analysis showed that engineered drainage significantly reduced the slip along major discontinuities, and thus had a strong impact on the model predictions.

Numerical modeling allows a deeper understanding of coupled fluid-mechanical mechanisms at play in high dam sites, including Baihetan.





Fig 11: Start of hydroelectric production - CCTV – June 28, 2021.

## 6. EPILOGUE

The project has successfully reached completion. Hydroelectric production started at the Baihetan site on 28 June 2021.

## 7. ACKNOWLEDGEMENT

The work reported here is the result of a team effort. The invaluable contributions of my colleagues Guotao Meng (HydroChina – Itasca R&D Center, Hangzhou, China), Zhao Cheng, Ryan Peterson, Varun, and Peter Cundall (Itasca Consulting Group, Inc., Minneapolis, MN, USA) are gratefully acknowledged. 🚀

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