Newsletter

AUSTRALIAN CENTRE FOR GEOMECHANICS
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Jabal Sayid paste plant

IN THIS VOLUME:

Commissioning Saudi Arabia's first (paste) backfill system

writes Paul Carmichael, Ma'aden Barrick Copper Company, Australia, and Rob Brown, Paterson & Cooke, Canada

Introduction

With Saudi Arabia looking to transform its economy, the domestic mining industry is a key focus and set for the growth that comes from the development of large scale, world class operations (Ellyatt & Gamble 2018). Ma'aden Barrick Copper Company's (MBCC) Jabal Sayid is the first of these operations, successfully leveraging on Barrick's extensive global mining expertise and Ma'aden's history of mining operations within the kingdom. Though successfully moving into full production, the operation's location, two hours south east of Medina, has Jabal Sayid positioned in a challenging region environmentally, logistically and culturally; demanding practical solutions to difficult problems.

Jabal Sayid operates as an underground sublevel open stoping operation where MBCC has endeavoured to implement a modern backfill system during the previous five years to allow the maximum recovery of the volcanogenic massive sulfide ore (VMS) deposit through pillarless mining. The key motivation of a modern system was to achieve production rates while confidently controlling the risks historically associated with underground backfill methods such as inrush, backfill failure during stoping, dilution and liquefaction.

A cemented pastefill was selected as the backfill of choice due to its strength properties, suitable rheology and use of the full tailings stream. Barrick relied on internal paste resources to develop the concept and retained GR Engineering for the detailed design. Paterson & Cooke (P&C) were drawn on to provide consultation on the initial plant design, complete preliminary laboratory testing, backfill design, document development, commissioning support, operator training and ongoing operational support for the backfill system. With their assistance, Jabal Sayid moved from the end of construction, through commissioning to full scale production in the space of approximately six months. This article outlines some of the challenges and

Continued page 2

processes involved in achieving the desired outcome of a commissioning process, while operating under the constraints of the Saudi Arabian desert.

Water and tailings

The most significant environmental challenge at Jabal Sayid is water scarcity. As no surface or groundwater is available, a fleet of 100+ trucks per day cart water from a treatment facility in Medina, 250 km to site. Therefore, water recycling is important on site and, as such, Jabal Sayid utilises a dry tailings storage facility (TSF). The tailings stream from the processing plant is separated into two streams: the cyclone underflow which is dewatered on a sand stacker (once earmarked for hydraulic fill); and the cyclone overflow reporting to pressure filters to recover process water and provide the fines portion at a high-solids concentration needed for paste. The two streams are then stored separately at the TSF for recombination at the paste plant. This separation introduces unique challenges, including ensuring the correct tailings report to the correct feeders at the paste plant, maintaining the correct particle size distribution (PSD) through tailings blend ratios, and ensuring foreign objects do not enter the tailings during the hauling and storage process to and from the TSF. This poses a risk of equipment damage and line blockage, if allowed to enter the paste plant and into the underground reticulation. These issues are not typical in the more common wet tailings feed paste plants, where the full tailings stream is pumped directly to slurry tanks at the paste plant. One benefit of the dry tailings is providing the paste engineer the ability to alter the paste PSD through changes in the ratio of addition of coarse and fine tailings. As PSD variations can have significant effects on strength and rheology, P&C identified the risks involved with manually recombining tailings streams and recommended a laser particle size analyser in the paste plant to closely monitor the feed and product PSD. This allowed tracking of the feed PSD by the national operators and has been incorporated into the routine QA/QC process onsite.

Underground delivery

With a nominal design flow rate of 225 m^3/hr, the paste reticulation system is gravity-driven and is made up of nominal 250 mm schedule 80 ceramic lined casing, 200 mm schedule 80 Victaulic trunk piping, and 250 mm PN16 HDPE stope piping. Diversion valves and friction loops are used to manage the flow underground. Pressures are logged continually, and the data is used to flag changes in flow properties and to model delivery to future stopes.

Engineering solutions in the paste plant and underground reticulation system were pivotal in the success of commissioning. P&C were involved throughout the project and, from their experience, recommended a number of engineering controls be installed. These included a high-pressure water flush pump, paste hopper and reticulation dump valves, an underground reticulation pressure sensor network, underground magnetic flow meter, paste pour point CCTV camera network, live barricade monitoring through NEWTRAX, and reticulation blockage/overpressure relief options. MBCC implemented these controls to ensure success of the pastefill system by providing maximum live information feedback to the paste plant operators to make decisions and develop their skills and knowledge base. For example, the high-pressure water pump with the ability to flush the reticulation at 3500 kPa, instead of typical plant air of 700 kPa, has provided a significant buffer for the operator inexperience during commissioning where operating without these controls would have seen a number of line blockage incidents, causing significant production delays. The implementation of these controls, albeit at a significant cost to the business, have cemented the value of designing a custom system, not one focussed solely on the feed materials and product, but its operating environment and the future cost to the business of downtime and capital underperformance.

Skilled labour

As the first backfill plant in the kingdom, an international team was employed to conceptualise the design and construct the 225 m^3/hr plant and underground reticulation system, though all operating is undertaken by national employees. With no experienced backfill operators and minimal processing plant experience available locally, the national team operated the plant through commissioning with minimal training and paste background knowledge. Along with the inherent language barriers, this challenge was managed safely through a number of methods.

Figure 1 Jabal Sayid paste plant

Figure 2 Jabal Sayid paste plant tailings storage, feeders and conveyors (coarse left and fines right)

From a personnel management perspective, close supervision and training, initially by P&C professionals and later by full-time experienced expatriate engineers, was key to the success of the commissioning process. Along with dayshift only, pastefill for the first two months included maintaining supervision, training and onsite incident response ability during all filling. The plant achieved sustained full production rates in approximately three months.

Through commissioning, test-pours and now full-scale operations, the live feedback provided to the operators through the multiple monitoring systems has helped develop confidence and understanding, while reinforcing the effect their decisions have on the strength, rheology, delivery and overall behaviour of the pastefill, ultimately setting them up for success as competent paste plant operators.

Result

By investing the required capital in designing and constructing a plant with surplus capacity, maintaining close supervision and training through commissioning and investing in engineering fail-safes and extensive monitoring systems, MBCC ensured full-scale paste production was achieved in a suitable time frame. Though not without commissioning issues such as line blockages, mechanical redesigns

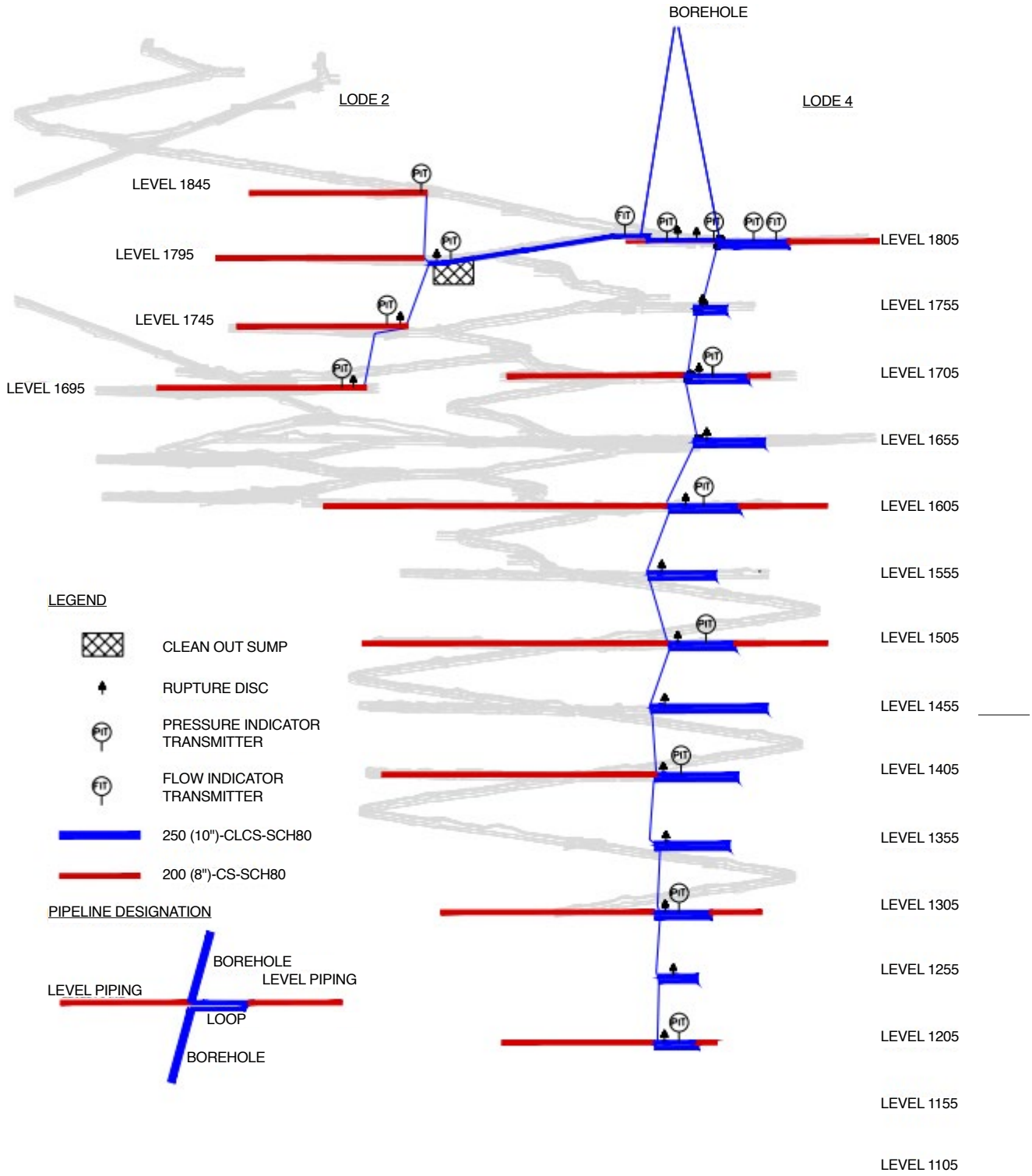


Figure 3 Jabal Sayid underground reticulation system

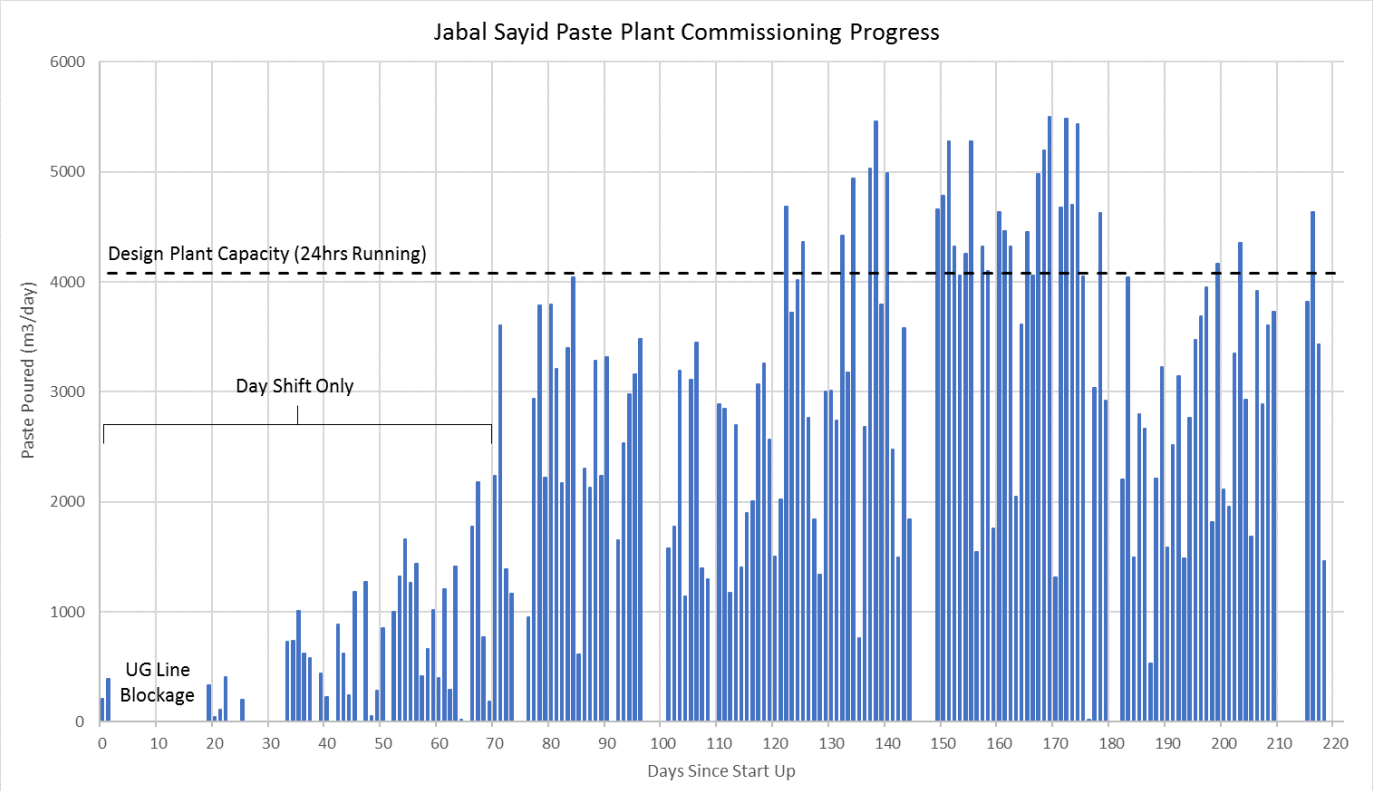


Figure 4 Jabal Sayid paste backfill production profile

and tailings feed consistency issues, the conservative throughput of the plant allowed for the reduction of the void backlog by 233,000 m^3 in the first seven months of operating while maintaining full mining production. Going forward, the plant is forecast to run at or below its design capacity, while successfully moving the bottleneck of the mining cycle back onto stope production, the goal of any backfill plant.

Reference

Elyatt, H Gamble, H 2018, 'Goodbye oil, Saudi Arabia's future economic growth will come from its mega-cities', CNBC, 23 January, accessed August 2018.

Paul Carmichael
Ma'aden Barrick Copper Company, Australia

Rob Brown
Paterson & Cooke, Canada

ACG Centre Director – Associate Professor Johan Wesseloo

Australian Centre for Geomechanics new director

In 2019, Associate Professor Johan Wesseloo was appointed director of the Australian Centre for Geomechanics (ACG) at The University of Western Australia, replacing Professor Yves Potvin who had been director since 2000.

Associate Professor Wesseloo joined the ACG in 2007 and has led the centre's premier research project, *Mine Seismicity and Rockburst Risk Management*.

A highly respected mining geomechanics industry practitioner and collaborative researcher with extensive experience and knowledge across many geomechanics disciplines, he has been involved in geotechnical engineering since 1998, with experience in both underground and open pit environments.

He developed a keen interest in mining induced seismicity, in the different aspects of geotechnical risk-based design, with application in open pit and underground scenarios. Before joining the ACG, Associate Professor Wesseloo was employed by SRK Consulting, Johannesburg.

"The ACG exists to serve the mining industry and, since its inception, has developed strong partnerships with industry," Associate Professor Wesseloo said. "It also needs to adapt to a changing environment, always with the aim of continuing to do what it does well: supporting the industry through research, training and technology transfer.

"This function is as vital as ever and, with several new technologies recently entering the geomechanics field, it is also important to help narrow the gap between the state-of-the-art and the state-of-practice.

"Research deliverables must be translated into practical tools which are underpinned by a further training and education platform."

Professor Potvin remains with the ACG as Professor of Mining Geomechanics, and continues to champion the ACG's leading industry-focused research projects, including the Ground Support Systems Optimisation Project and the Stope Reconciliation and Optimisation Project.

He will continue to work closely with the mining industry to develop new research projects and participate on geotechnical review boards. Professor Potvin will proceed with his mandate to encourage and mentor younger geotechnical professionals with their research and career aspirations.

The Board acknowledged Professor Potvin's outstanding and sustained

contribution to geomechanical excellence and thanked him for his leadership, industry insight and vision.

"This change of leadership at the ACG enables the younger generation to take the centre to its next level," Professor Potvin said. "The ACG currently has a significant pool of talent ready to take more responsibilities. It is also in a very solid financial situation and a position to invest in further growth."

Associate Professor Richard Jewell

1933 - 2020

Associate Professor Richard Jewell was instrumental in establishing the ACG in 1992, where he was director from 1992 to 2000. Richard passed in late September 2020 at the age of 87. He is fondly remembered by his ACG family, and former industry colleagues and academics as a true gentleman, inspiring mentor, and energetic tailings champion.

Richard commenced his career at UWA as a lecturer in 1972, and retired in 2000. Until only recently, he remained active in the ACG's tailings initiatives as an external consultant, a testament to his love of environmental geomechanics and his popularity throughout the global mining community.

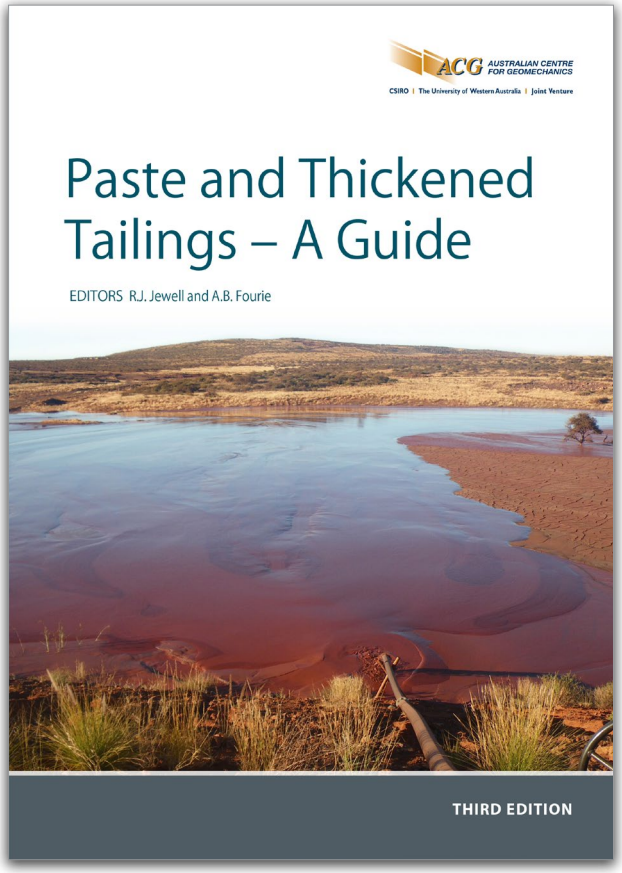
In 1984, Richard was responsible for founding the Geomechanics Group within the Department of Civil Engineering, where he was pivotal in developing the geotechnical centrifuge facility. He was a wonderful strategist and influencer, by using his extensive networks within W.A., he persuaded Main Roads and UWA to provide funding to establish the centrifuge, at that time the largest facility of its kind in the southern hemisphere. He was also heavily involved in laboratory and field testing to provide a design basis for the Woodside Goodwyn A Platform. This project, and the sustained collaboration with Woodside, laid the foundation for the expansion of the geomechanics laboratory at UWA.

Richard brought to life the ACG International Paste and Thickened Tailings Conference series in the late 1990s. Richard co-chaired this popular conference from inception, and retired from this role at the 21st International Conference on Paste & Thickened Tailings held in Perth in 2018.

Richard was co-editor of the three editions of the well-read ACG *Paste & Thickened Tailings – A Guide*, and co-editor of over 20 conference proceedings.

Amongst many other projects, Associate Professor Jewell managed a large research project on Saline Tailings Disposal and Decommissioning in the mid 1990s, sponsored by the Minerals Research Institute of Western Australia and industry.

The extraordinary legacy and positive impact Richard made, not only through the halls of the UWA Crawley Engineering Building and in the boardrooms of mining companies, is cherished and respected by so many. Today, the ACG counts close to 20 staff and researchers, an incredible achievement from the initial seed Richard planted almost 30 years ago.



The ACG Paste & Thickened Tailings – A Guide Third Edition, co-edited by Associate Professor Richard Jewell

Unsaturated Soils Guidelines – Volume 1

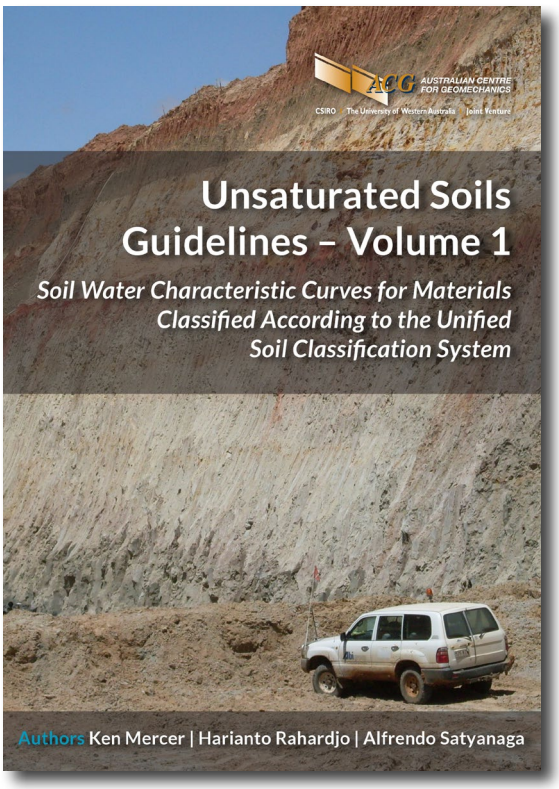
Soil-Water Characteristic Curves for Materials Classified According to the Unified Soil Classification System

In 2019, the ACG published the *Unsaturated Soils Guidelines – Volume 1*. Authored by Dr Ken Mercer, 3rd Rock Consulting, Professor Harianto Rahardjo, Nanyang Technological University (NTU), Singapore, and Dr Alfrendo Satyanga, formerly NTU, these guidelines detail the key aspects and behaviour of unsaturated soils. The publication provides industry personnel with the information that will assist them in managing these work areas and to relate to and brief their design consultants.

Of unsaturated soil mechanics importance is the use of the soil-water characteristic curve (SWCC). Over the years, it has emerged as key to the implementation of unsaturated soil mechanics within the engineering practice. Additionally, industry research has focused on 'estimation protocols' for both the SWCC and the subsequent unsaturated soil property functions (USPFs), such as unsaturated permeability function and unsaturated shear strength.

Analysis and design in geotechnical engineering have been driven by computer-solved numerical solutions. Initially, the numerical models focused mainly on the saturated soil zone and were known as 'saturated only' analyses. The present norm is for the numerical models to simultaneously simulate both the saturated and unsaturated soil zones.

This publication's collection of data and the analysis of previously collected data are of considerable value to numerical modellers. This volume forms a seamless means of embracing the saturated and unsaturated zones of the soil profile into a single analysis.



This unique publication provides geotechnical and mining engineers, and soil scientists, with initial-order estimation for calculating USPFs, which may assist many engineering projects. Alternatively, these initial estimations of unsaturated soil properties may simply serve as an indicator that further laboratory testing on soil samples is required in order to have a trustworthy engineering design. The guidelines seek to assist the global mining industry to establish protocols for the determination of unsaturated soil properties.

Unsaturated Soils Guidelines – Volume 1 was developed with funding and support from:

- Australian Centre for Geomechanics
- E-Precision Laboratory
- Iluka Resources Limited
- Rio Tinto

This publication can be purchased at acg.uwa.edu.au/unsats

Accessing geomechanical excellence

ACG Online Repository of Conference Proceedings

There are many papers from international mining conferences, freely available to download from the Online Repository of Conference Proceedings.

View them now at papers.acg.uwa.edu.au

ACG publication – Ground Support for underground mines

Authored by Professor John Hadjigeorgiou, University of Toronto, Canada, and Professor Yves Potvin, Australian Centre for Geomechanics, The University of Western Australia, Australia

The ACG is dedicated to conducting geomechanical research, sharing knowledge and providing education to industry with a view to improving safety, maximising economic return and reducing environmental impacts of mining activity. As a result of considerable hard work towards these goals, the ACG was delighted to release *Ground Support for underground mines*.

Ground Support for underground mines was written in response to industry's need for a new book on ground support, with the target audience being practicing geotechnical and mining engineers who have the task of designing ground support systems in mines. It is a valuable resource for all underground mining professionals, researchers and university students. The authors have undertaken to describe existing and novel ground support design methods, and to provide practical tips and advice on the design process.

Background

In 2013, the ACG commenced the international research project, Ground Support Systems Optimisation (GSSO), to explore whether it is possible to optimise ground support systems with the aim to maintain, if not improve, mine safety while reducing costs and/or time components. The project featured three sub-projects: probabilistic ground support design; the use of numerical modelling for ground support design; and benchmarking of current ground support design practices. The results from these sub-projects fed into the writing of a new comprehensive, yet practical, underground mining support book.

The GSSO research project is currently in its second phase, which is due for completion in September 2021.

Authors

The book was authored by Professor John Hadjigeorgiou, University of Toronto, Canada and Professor Yves Potvin, Australian Centre for Geomechanics, The University of Western Australia, Australia, with contribution from selected experts on specific topics.

Sponsors

The *Ground Support for underground mines* book was developed with funding and support from a number of industry sponsors.

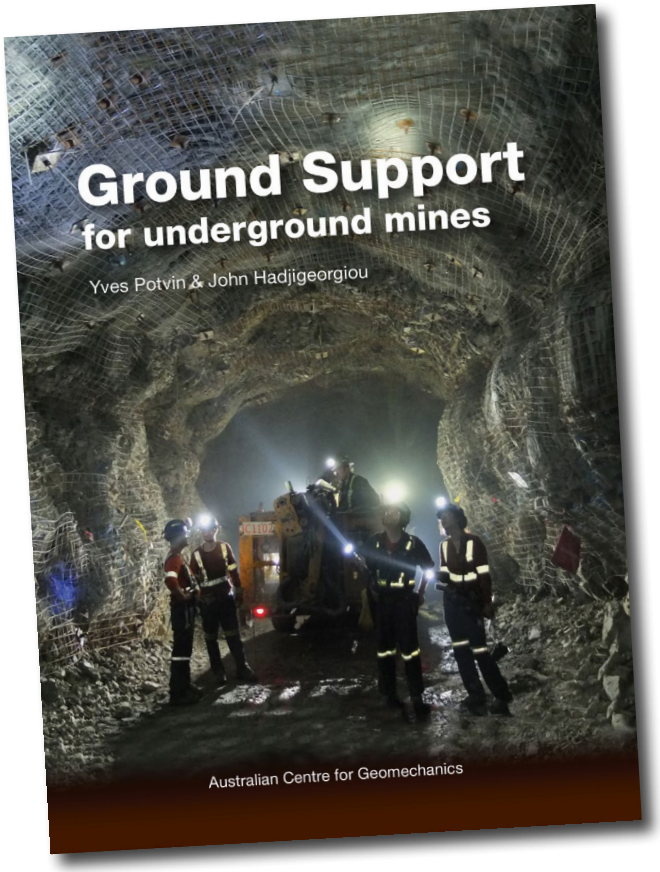
Major project sponsors:

- Minerals Research Institute of Western Australia
- Codelco Chile
- Glencore Mount Isa Mines
- IGO Limited
- MMG Limited
- Australian Centre for Geomechanics

Minor project sponsors:

- Atlas Copco Australia Pty Limited (now Epiroc)
- DSI Underground
- Fero Strata Australia (now DSI Underground)
- Golder
- Geobrugg AG
- Jennmar Australia

The book is available for purchase at acg.uwa.edu.au/shop/gsso



Ground Support in Underground Mining Course

Half days, 8 am – 12:30 pm
17–21 October 2022
Online and in-person
Perth, Western Australia

acg.uwa.edu.au/events

An overview of bench design for cut slopes with an example of an advanced dataset assessment technique

by Sharla Coetsee, Reutech Mining, South Africa

Bench height and berm width contribute to the inter-ramp geometry on which an overall slope design is based. It is imperative to ensure the inter-ramp geometry is sound and the design berm width is sufficient to maintain the berm retention factor selected and therefore the anticipated volume of failed material should an instability occur. The berm retention factor, rock mass and geometric conditions of the discontinuities for a selected design sector inevitably defines the berm width during the design process. The berm retention factor is of paramount importance for the mitigation of rockfall which is dependent on the percentage of the volume of material that exceeds the berm width.

Bench design analysis is conducted using industry best practices, previous project history, engineering judgement and published criteria. These criteria are either empirical or formula based, and typically encompass varieties of the input parameters which include bench height, bench face angle, plunge of the intersection of the joints, the angle of repose, the volume of spill material, and the bulk or swelling factor.

The Ritchie Criterion (Ritchie, 1963), the minimum berm width (Piteau & Martin, 1977), the Modified Ritchie Criterion (Hustrulid, 2000), the minimum berm width using either conical or pyramidal spill radius (Gibson, de Bruyn & Walker, 2006, adapted and applied by Rocscience), and the minimum berm width presented by Haines, Voulgaris, Walker & de Bruyn (2006) are published berm design examples.

Figure 1 Example of a wedge instability on a bench scale

The likelihood of achieving a design is highly reliant on attaining the bench face angle with specific reference to the bench crest, the associated break back limit, as well as frozen toes which define the final excavated angle. Break back is controlled by the local structural geology and the reduction in shear strength of the discontinuities. Frozen toes occur due to errors in pre-split application.

Overview of empirical bench design methods

Ritchie (1963) is the first publication to deliberate the concept of the design of berm width and ditch construction to adequately contain rockfall for highway shoulders. A relationship between the width of the fallout versus the height and angle of the slope is illustrated for selecting adequate berm width for design, and is known as the Ritchie Criterion.

In March 1977, Piteau & Martin presented formula for designing the minimum berm width required for bench design for open pit slopes. This is the first instance whereby the cross-section and the dip or plunge of the intersection were included, as well as the angle of repose. However, this formula does not take the true geometry of the wedge or the bulk/swelling factor into consideration.

Martin & Piteau (June, 1977) illustrate two methods that slope design can be based on; a conservative or managed approach. A process for calculating the cross-sectional area of the instability, the radius of the failed material taking the angle of repose into account, and the minimum berm width required to hold the instability size, is based on their earlier work.

Pierson, Davis & Pfeiffer (1994) introduce the Oregon Ditch Standard, which is founded on a number of tested rockfall scenarios for determining the required berm width for a highway shoulder. They discuss that ditches true to the Ritchie Criterion are seldom constructed and, therefore, the criterion has been adjusted and is not actually applicable as it is not an accurate reflection of the design recommendations. The Oregon Ditch Standard is not typically applied to bench design analysis for open pit slopes, however, the key points remain pertinent to the design concept.

Hustrulid (2000) debate the Modified Ritchie Criterion, which considers rockfall. However, the applicability of the criterion due to the fact that ditches are not implemented is not highlighted as in Pierson, Davis & Pfeiffer (1994). The Modified Ritchie Criterion is considered to be conservative for containing rockfall. As the problem of rockfall and failed material containment is complex, they suggest a risk-management perspective should be taken into consideration when compiling an open pit design.

Gibson, de Bruyn & Walker (2006) present a new methodology for calculating spill radii utilising a conical (does not take wedge geometry into account), and pyramidal (does take wedge geometry into account), distribution of failed material. Between the two formulae, it is recommended that the lesser of the two spill radii values is utilised for design purposes. The principal design components for berm width, such as the angle of repose, swelling or bulk factor, as well as the bench retention factor are included in the formula.

Haines, Voulgaris, Walker & de Bruyn (2006) illustrate a formula for the derivation of spill berm width using a bulk or swelling factor of 1.5. Martin & Piteau (1977) also stated an adjustment factor of 1.5 for the swelling or bulk factor, should it have been excluded. It would appear that the formula does not take the angle of repose, bench retention factor, nor the failure geometry into account. Although not published in these papers, there is no reason why the bench retention factor should not be applied to the volume utilised in the formula.

Jermy, Kuppusamy, Fietze & Hornsby (2011) conduct a comparison of the Modified Ritchie Criterion (Ritchie, 1963), which provided a static berm width, with the Haines Criterion (Haines, Voulgaris, Walker & de Bruyn, 2006), and the conical distribution formula from Gibson, de Bruyn & Walker (2006), which tended to overestimate the berm widths required, as the wedge geometry and failed material distribution were not taken into consideration. The pyramidal Gibson formula (Gibson, de Bryun, & Walker, 2006) did however offer a more realistic estimate of the design berm width. Figure 1 shows a classic example of a wedge instability on a bench scale for illustrative purposes. In this case, the run-out is limited to approximately two meters, with a single rock having rolled six meters from the failed mass.

Gibson & Paul (2016) conduct a comparison of the Gibson formula (Gibson, de Bruyn & Walker, 2006). The results

obtained using Frac_Rock demonstrates that the Gibson formula overestimates the berm width required by approximately 10 to 20%.

Table 1 is a comparison of the published criteria, and notes if they are empirical or formula based, and which design factors where applied.

Advanced dataset assessment technique

When compiling a berm design model, in assigning a derived (calculated) friction angle and cohesion value, the Factor of Safety (FoS) and Probability of Failure (PoF) for a suite of kinematically identified plane or wedge sliding instabilities may be overestimated, and may not be representative of true mining conditions. As shear strength properties change over the life of mine (LOM), so does the FoS. Assuming that the FoS is static and the derived PoF is indefinitely valid, this may result in a design that is insufficient in maintaining the berm retention factor selected.

The friction angle may be assigned based on values that are residual, weakened or averaged, or based on a static approach or a sensitivity analysis. The cohesion value may be selected based on a nominal, a weakened state, a static approach or sensitivity analysis. These concepts are described by Piteau & Martin (1977), Whyatt, Miller & Dwyer (2004), Gibson, de Bruyn & Walker (2006) and Jermy, Kuppusamy, Fietze & Hornsby (2011) respectively.

The conditions of the discontinuities in the rock mass of the bench face cannot be accurately allocated for a long-term scenario. Practical considerations such as raveling, the time period of exposure, climate and weathering such as freeze and thaw or expand and contract cycles and blasting practices have a combined and accumulative effect on the reduction of shear strength of the discontinuities over the LOM.

Opposed to applying a dataset cut-off to the calculated FoS (as applied by Holley, Skayman & Zhiwei, 2006), for the planar or wedge instability spill volume, the use of all data, regardless of the FoS or spill volume, is required in order to accurately ascertain the minimum berm essential to hold all instability scenarios. This is based on the evaluation of all spill volumes and spill radii. This methodology allows for the assessment of the minimum berm widths calculated using the published criteria and detailed dataset analyses methods.

It is suggested that two plots illustrating the percentage of instabilities per spill radius bin (meter increments), and the break back distance range per spill radius (same meter increments), be compiled using the datasets from each planar and wedge combination model per selected section line without any design criteria being applied to first determine the range, concentration and worst case scenarios.

This analysis technique provides a realistic process to define the minimum berm width required per section line, per failure mode.

By comparing the minimum berm width and the anticipated break back associated per geometric iteration for planar or wedge sliding, the effective berm width can be derived and compared to the proposed berm width for geometric design of the pit slope wall, validation or optimisation. This procedure allows for a robust design approach that encompasses all eventualities, and will ensure that the berm width and the berm retention factor is valid for the LOM.

See the full paper at https://papers.acg.uwa.edu.au/p/2025_47_Coetsee/

Sharla Coetsee
Reutech Mining, South Africa

Table 1 Comparison of the published criteria

Criteria	Reference	Empirical	Bench height (m)	Bench face angle (°)	Plunge of intersection (°)	Angle of repose (°)	Volume of material (m^3)	Bulk or swell factor
Ritchie Criterion	Ritchie (1963)	Yes	Yes	Yes	–	–	–	–
Modified Ritchie Criterion	Hustrulid (2000)	Yes	Yes	Yes	–	–	–	–
Minimum required berm width	Piteau & Martin (1977) and Martin & Piteau (1977)	–	Yes	Yes	Yes	Yes	–	Yes
Oregon Ditch Standard	Pierson, Davis & Pfeiffer (1994)	Yes	Yes	–	–	–	–	–
Haines minimum berm width	Haines, Vougaris, Walker & de Bruyn (2006)	–	–	–	–	–	Yes	Yes
Gibson minimum berm width conical	Gibson, de Bruyn & Walker (2006)	–	Yes	Yes	–	Yes	Yes	Yes
Gibson minimum berm width pyramidal	Gibson, de Bruyn & Walker (2006)	–	Yes	Yes	Yes	Yes	Yes	Yes
Modified Gibson minimum berm width	Gibson & Paul (2016)	Yes	Apply a reduction of between 10 and 20% to either formula					

2020 Event Reports

writes Candice McLennan, Australian Centre for Geomechanics, Australia

2020 International Symposium on Slope Stability in Open Pit Mining and Civil Engineering

The 2020 International Symposium on Slope Stability in Open Pit Mining and Civil Engineering (Slope Stability 2020) was to be held in May 2020, and when the global COVID-19 pandemic hit earlier that year, all plans were turned on their head as national and state governments in Australia imposed a lock down with restrictions on public gatherings of people. With much deliberation, the Slope Stability 2020 committee, along with Symposium Chair Professor Phil Dight of the Australian Centre for Geomechanics, decided to proceed with an online offering, rather than cancel or postpone the event. This would be the first online only event held by the ACG in it's then 28 year history.

The online format of the event presented not only a steep learning curve for ACG staff, but also a downturn in attendance numbers with projected in-person attendees set to reach 550-600, and actual online attendees numbering 250.

This final number of attendees comprised 92 presenters, 42 sponsor affiliations and 116 from industry. Twenty-nine different countries were represented at the online event, covering 11 different time zones.

The 92 online presentations were pre-recorded and amounted to over 36 hours of technical content, which was available 'live' during the three days of the conference to facilitate the question and answer/chat functionality, and on-demand for the 12 months following.

Keynote speakers for the symposium included Carolina Ahumada, BHP, with her presentation 'BHP's mine water management integrated approach to manage risk and optimise resource value'; Robert Sharon, Sharon Geotechnical LLC, who spoke on 'Slope performance monitoring – system design, implementation and quality assurance'; Dr John Simmons, Sherwood Geotechnical & Research Services, with 'Geomechanics of Australian open cut coal mining'; and Tim Sullivan, PSM, who presented 'Hydromechanical coupling concepts for mine slopes'.

Topics covered by the conference presenters included safety and risk management, processing of geotechnical data and limit design, assessment and implications for uncertainty in design, numerical analysis, in situ stress and displacement design of slopes, open pit/underground interaction, rockfall analysis and control, surface water and groundwater management, depressurisation, monitoring and remediation, slope design implementation, excavation control, blasting and legacy issues for final walls, and quality control.

The ACG was very grateful to have the support of 14 sponsors for the online event, including Reutech who was the Principal Sponsor, and Major Sponsors BHP, Geobrugg, GroundProbe, IDS GeoRadar, Itasca and Newmont Australia.

Sponsors provided promotional videos and documents that were available from their 'virtual booths' for the duration of the event. Thank you to all of the sponsors and exhibitors for their support of this event.

The papers from the Slope Stability 2020 Symposium are openly accessible from the ACG Online Repository of Conference Proceedings, courtesy of the Open Access Sponsor, SRK Consulting. View them at papers.acg.uwa.edu.au/ss2020.

The ACG thanks all participants in this online event: speakers, authors, reviewers, sponsors and exhibitors who all rose to the challenge of the last-minute change to the online format.

Second International Conference on Underground Mining Technology

The Second International Conference on Underground Mining Technology (UMT 2020) was held in Perth, Australia, 3-4 November 2020. The conference was the first hybrid event hosted by the Australian Centre for Geomechanics (ACG), with 20 delegates in attendance, and 58 virtual attendees participating via the online platform.

UMT 2020 was chaired by Associate Professor Johan Wesseloo, ACG director. There were 22 speakers, seven sponsoring/exhibiting companies, and ten countries represented from around the world.

On the day prior to the conference, the Monitoring Performance of Underground Excavations Hybrid Workshop was held, which attracted 35 attendees. This workshop was sponsored by Canary Systems Inc., Master Builders Solutions, and Sika. The workshop covered two main themes of technologies: focussing on convergence measurements from repeated laser surveys, and conventional instrumentation. The workshop facilitator was Professor Yves Potvin, ACG.

The two-day technical conference programme contained a total of 25 presentations, representing authors from 16 countries around the world. Themes covered in the nine plenary sessions included: machine learning, seismicity, paste, monitoring, stope design, ground support, and fundamental rock mechanics.

Day one of UMT 2020 began with the keynote presentation, *Mobile LiDAR for Underground Geomechanics: learnings from the Teens and Directions for the Twenties*. This was presented by Even Jones, BHP. The second keynote was delivered by Dr Jonny Sjöberg, Itasca Consultants AB, Sweden, in the final session of the day. This keynote was entitled, *Solving Rock Mechanics Issues through Modelling: Then, Now and in the Future*.

Day two included two more keynote presentations: the first being *Breaking New Ground: Challenges and Opportunities for Maximising Value from Underground Blasting* by Dr Ewan Sellers, CSIRO and Mining3; and the second keynote, *Recovery and Flow in Cave Mining: Current Knowledge Gaps and the Role of Technology in the Future*, delivered by Dr Alex Campbell, Beck Engineering Pty Ltd.

The ACG team greatly appreciates the support of the UMT 2020 sponsors and exhibitors. We were delighted to have Canary Systems Inc. as the Principal Sponsor of the event. Major Sponsors were Master Builders Solutions and Sika. Thank you to all of the sponsors and exhibitors for their highly valued participation.

The UMT 2020 Conference papers are openly accessible at the ACG's Online Repository of Conference Proceedings and can be freely downloaded at papers.acg.uwa.edu.au/umt2020, courtesy of the Open Access Sponsor, DSI Underground. The Online Repository aims to provide the mining geomechanics fraternity with open access, peer-reviewed conference proceedings, to assist in maintaining and developing skills, knowledge and capabilities. There is a large catalogue of published conference papers, covering topics across the geotechnical mining spectrum, available to all.

The ACG team extends sincere thanks to all of the UMT 2020 delegates (both in-person and online), speakers, authors, reviewers, sponsors and exhibitors for their contributions towards this conference, and helping it to be a success.

Bookmark acgugminetech.com for up-to-date information on upcoming conferences on underground mining technology, and visit acg.edu.au/events/ for information on all of ACG's upcoming events.

ACG Online Repository of Conference Proceedings

ACG's online repository continues to grow and become an invaluable open access resource for industry and academia

The ACG Online Repository of Conference Proceedings (Repository) is the leading open access mining geomechanics repository, established as part of the ACG's commitment to sharing mining research, knowledge and education to both industry and academia.

Covering the broad range of underground, open pit, mine closure, and paste, thickened and filtered tailings (PTT) disciplines, the Repository is home to 2,579 peer-reviewed papers from 48 ACG and co-hosted international mining events, of which 1,900 have been made freely available to industry. It has proven to be a valuable resource to the mining community. There are 709 underground, 315 open pit, 412 mine closure, and 464 PTT papers, with more than 500,000 paper downloads since Repository inception in March 2017.

The 2020 International Symposium on Slope Stability in Open Pit Mining and Civil Engineering, the Second International Conference on Underground Mining Technology, and the 23rd International Conference on Paste, Thickened and Filtered Tailings papers were made available during 2020.

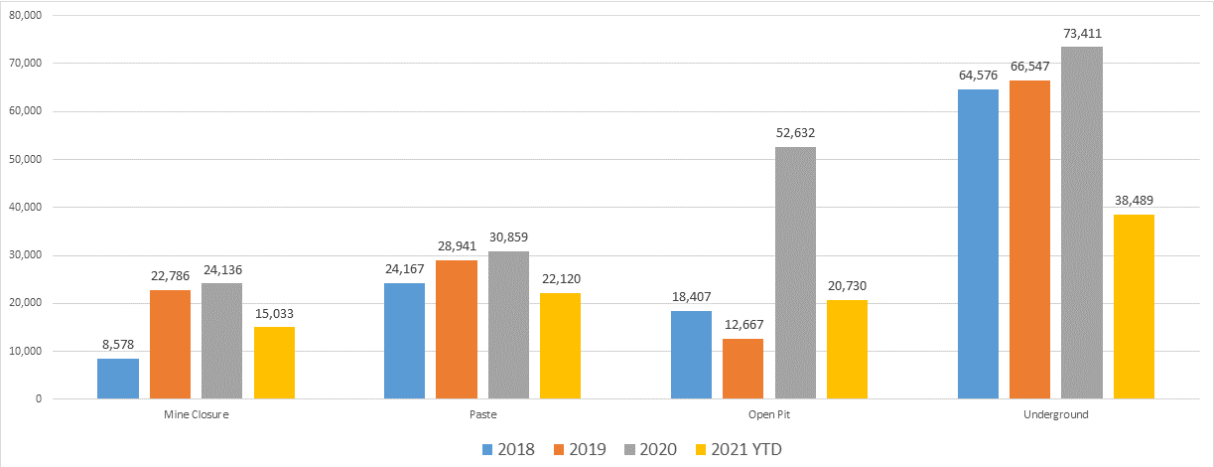
During 2019, papers from the 13th International Conference on Mine Closure, Ninth International Symposium on Ground Support in Mining and Underground Construction, and the 22nd International Conference on Paste, Thickened and Filtered Tailings became freely available from the Repository.

Since the start of the pandemic, the Repository has demonstrated a positive trend with a growth of over 38% from 2019 to 2021, and an increase in average monthly paper downloads of 15,087 per month compared to 10,912 per month in 2019.

Accessing geomechanical excellence

The below chart details the annual year on year growth of paper downloads by each mining geomechanics discipline. The 2021 end of year forecast is to exceed 200,000 paper downloads, after exceeding 180,000 downloads in 2020. This represents a forecast 20% year over year growth.

Visit the online repository at papers.acg.uwa.edu.au



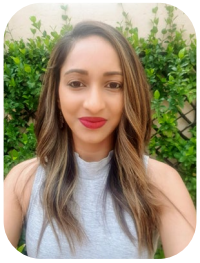
ACG Online Repository of Conference Proceedings – yearly paper downloads by mining geomechanics discipline. Source: ACG internal analysis as at November 2021

ACG Staff Update

Introducing some of our new team members. View the full ACG team at acg.uwa.edu.au/acg-team

Dr Matthew Heisnen Egan
Software Engineer – mXrap

Joseph Mbenza
Research Fellow – Ground Support Systems Optimisation



Denisha Sewnun
Research Fellow – mXrap

Dr Hongyu Wang
Research Associate

ACG event schedule*

Australian Centre for Geomechanics | Volume No. 47 | December 2021

ACG AUSTRALIAN CENTRE FOR GEOMECHANICS
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2022/2023

mXrap User Case Studies for Mines Seminar	14 March 2022 | Perth, Western Australia
Geomechanics Data for Underground Mines Course	15–18 March 2022 | Perth, Western Australia
Mine Fill Seminar	4–7 April 2022 | Perth, Western Australia
Geotechnical Design for Underground Metalliferous Mines Course	16–20 May 2022 | Perth, Western Australia
Introduction to Open Pit Slope Stability Course	13–17 June 2022 | Perth, Western Australia
Blasting Practices for Wall Control in Open Pit Mines Seminar	8–12 August 2022 | Perth, Western Australia
Cave Mining Workshop: From Data to Design	29 August 2022 | Adelaide, South Australia
Caving 2022 | acgcaving.com	30 August – 1 September 2022 | Adelaide, South Australia
Mine Closure 2022 | acgmineclosure.com	4–6 October 2022 | Brisbane, Australia
Ground Support in Underground Mining Course	17–21 October 2022 | Perth, Western Australia
Mining at Depth Seminar	7–11 November 2022 | Perth, Western Australia
Geotechnical Design and Implementation for Open Pits Course	21–25 November 2022 | Perth, Western Australia
Ground Support 2023 | acggroundsupport.com	12–14 September 2023 | Perth, Western Australia
SSIM 2023 | acgsurfacemining.com	14–16 November 2023 | Perth, Western Australia

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*The ACG event schedule is subject to change. CRICOS Code: 00126G

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CAVING

Caving 2022

Fifth International Conference on Block and Sublevel Caving

30 August – 1 September 2022 | Adelaide, South Australia

ABSTRACTS DUE 9 MARCH 2022

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References

An overview of bench design for cut slopes with an example of an advanced dataset assessment technique

by Sharla Coetsee, Reutech Mining

References from page 9.

Gibson, WH, de Bryun, A & Walker, DJ 2006, 'Considerations in the optimisation of bench face angle and berm width geometries for open pit mines', Proceedings of the International Symposium on Stability of Rock Slopes in Open Pit Mining and Civil Engineering, The Southern African Institute of Mining and Metallurgy, Johannesburg, pp. 557–578.

Haines, A, Voulgaris, P, Walker, D & de Bruyn, I 2006, 'Geotechnical design considerations for the proposed Oyu Tolgoi open pits, Southern Mongolia', Proceedings of the International Symposium on Stability of Rock Slopes in Open Pit Mining and Civil Engineering, The Southern African Institute of Mining and Metallurgy, Johannesburg, pp. 133–154.

Hustrulid, WM 2000, Slope Stability in Surface Mining, Society for Mining, Metallurgy, and Exploration, Littleton.

Jermy, C, Kuppusamy, V, Fietze , CP & Hornsby, PK 2011, 'Open pit bench failure volume analysis and berm design – is it realistic?', Proceedings of the International Symposium on Rock Slope Stability in Open Pit Mining and Civil Engineering, Canadian Rock Mechanics Association.

Piteau, D & Martin, DC 1977, 'Slope stability analysis and design based on probability techniques at Cassiar Mine', CIM Bulletin, vol. 70, no. 779.

Read, J & Stacey, P 2009, Guidelines for Open Pit Slope Design, CSIRO Publishing, Collingwood.

Ritchie, A 1963, Evaluation of Rockfall and its Control, Washington State Highway Commission, Washington.

Whyatt, J, Miller, S & Dwyer, JG 2004, NIOSH Computer Programs for Bench Crest Failure Analysis in Fractured Rock, The National Institute for Occupational Health and Safety, Cincinnati, https://www.cdc.gov/niosh/mining/UserFiles/works/pdfs/ncpfb.pdf.