SANIRE
SOUTH AFRICAN NATIONAL INSTITUTE OF ROCK ENGINEERING

ROCK talk

Volume 8, Issue 4 | December 2022

PRESIDENT'S CORNER

Dear SANIRE member,

What a year! Thank you for being part and in full support of SANIRE in 2022. I am truly humbled by having the opportunity to lead such an inspiring institute.

I hope you have had the opportunity to be a part of something memorable this year with SANIRE, whether you attended a branch meeting, a technical event, dialed in for a webinar, accessed information through our website, participated in the exams or photo competitions, or simply received our newsletter.

WHAT'S INSIDE

PRESIDENT’S CORNER

Beyond the obvious successes this year, there are so much more that we can be proud of:

- We have grown to a record number of membership with just under 700 members.
- The symposium and banquet were well attended and a great success.
- SANIRE’s RockBowl team won at the ISRM LARMS International Rockbowl Competition in Paraguay.
- SANIRE’s female membership numbers increased by 4% from 2021 to 2022, which makes our female membership now a quarter of SANIRE’s total membership.

It has been a great year for 2022, and this has inspired me and brought me great excitement for the year 2023.

On behalf of SANIRE Council, I wish everyone an enjoyable and relaxing festive season.

SANIRE greetings,

Lizelle Prinsloo
SANIRE President

SANIRE Banquet 2022

The SANIRE presidential banquet was such a great success. It is indeed something to always forward to. The photographer has captured the moment very well.

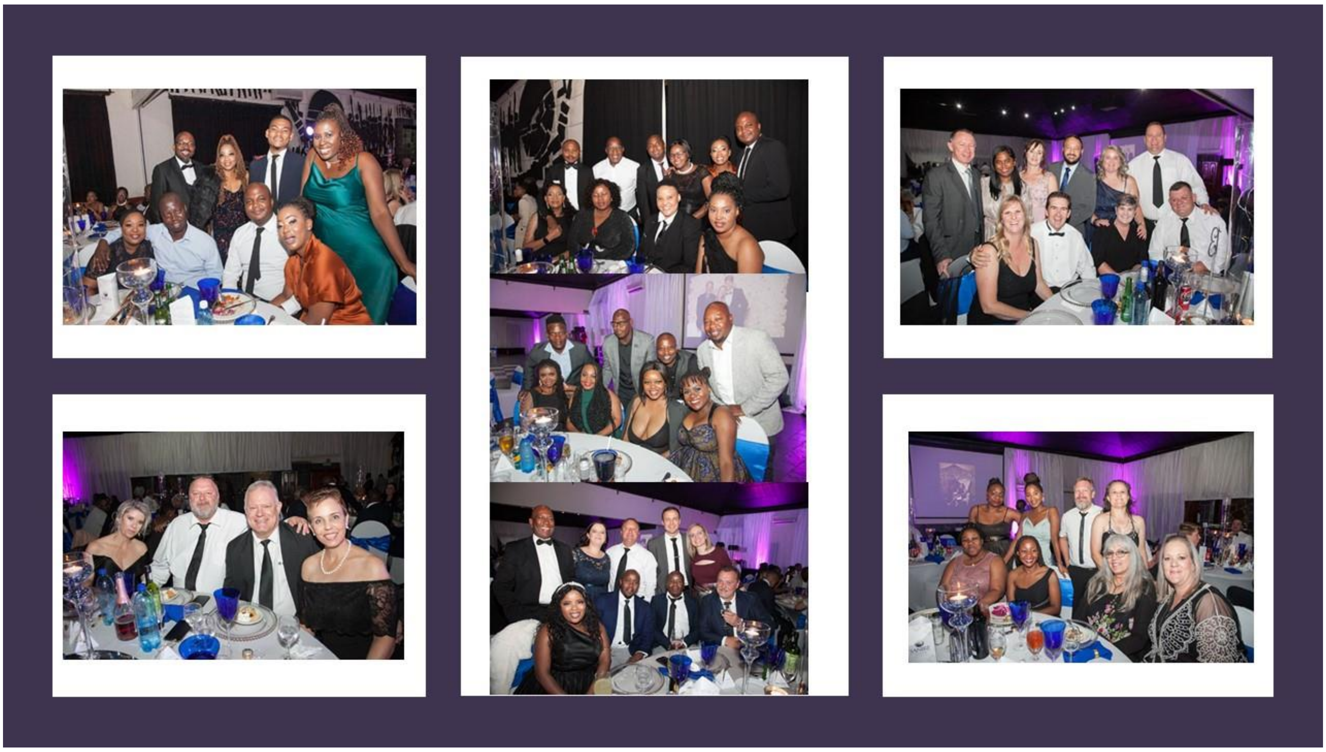










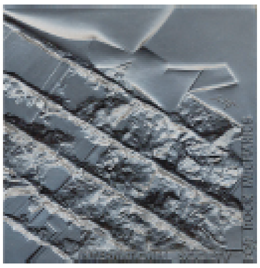



SANIRE Awards

Congratulations to our award winners during the 2022 presidential banquet. Keep doing the good work and make the mining industry a safe place

ROCHA MEDAL 2023

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 2023.
Full details on the Rocha Medal are provided in ISRM By-law No. 7.

Application

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

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

Nominations shall be 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 2021.

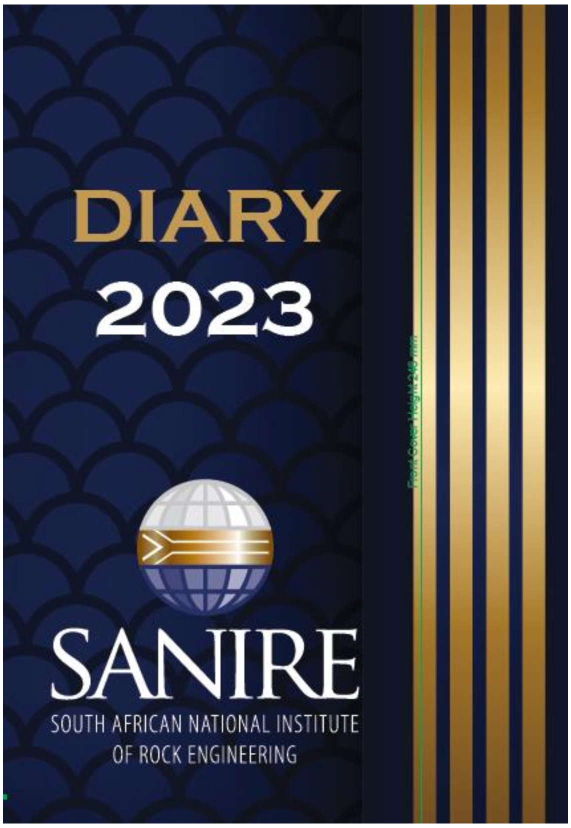
Past Recipients

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

SANIRE Diary Project 2023

A new year is a new beginning, an opportunity to start over and build better.

Please get your free SANIRE diary from your branch chairperson.



A SPECIAL CONGRATULATIONS

A special congratulation to Franz for obtaining all mining methods RMC. Franz started his career in 2013 as a Rock Engineering Graduate with Anglo American Platinum following the completion of his Honours Degree in Engineering Geology at the University of Pretoria.

As was the requirement for all Rock Engineering graduates, Franz continued his studies, obtaining his Strata Control Certificate in September of the same year and his Rock Engineering certificate for Metalliferous mining in February of the following year (2014).

After obtaining his first ticket, Franz was moved to Anglo's Amandelbult Complex as a Shaft Rock Engineer during June of 2014. During his time at the Amandelbult Complex, the company started an Open Cast project to extract the remaining shallow reserves on the complex.

Franz was afforded an opportunity to be involved in the design of the pits and used this opportunity to complete his Open Cast ticket which he obtained in January of 2017. During April 2017, Franz took up an opportunity at Sasol Mining in the Secunda coalfields and started working towards his Coal ticket which he completed in October of 2018.

During July 2019, Franz was afforded an opportunity to further his experience, joining the team at Middindi Consulting. It was during his time with Middindi, when he first received exposure to massive mining. Concurrent to this, Franz started his MSc. Eng. through the University of Witwatersrand in 2019 eventually graduating in 2021.

In April 2021 Franz moved back to the Amandelbult Complex, re-joining Anglo Platinum as Chief Rock Engineer for Tumela Mine. Following the move back to Anglo, Franz was fortunate enough to be provided the data for the Sandsloot Underground Project which investigated the feasibility of establishing a massive mine below the dormant open pit. This project afforded him the opportunity to compile his portfolios for the Massive ticket, which he completed during November 2022.

At present Franz is employed as the Chief Rock Engineer for the Amandelbult Complex and still enjoys the field of rock mechanics and the interesting challenges that this profession brings.

EDUCATION OF THE FUTURE

After some years there has been activity on the side of the future education portfolio. The MQA contact SANIRE council requesting a workshop to set the exit assessment protocol for both Level 4 qualifications, Coal and Hard Rock strata Control Practitioners. As it is well know that the qualifications are in existence for some time now, learnership could not have been registered as there was no exit assessment to the qualification(s). The workshop was initiated and included the current education portfolio (theory and practical examinations), however shortly into the discussions it was clear that the gap that was created by the lack of progress was to big to cross. Together with this, the qualifications need to be reviewed in 2023, on which Council though it best to postpone the assessment workshop until the review has been completed. This would allow all SANIRE experts invited to sit on the panel of reviews to be brought up to speed of the process for curriculum development and align current practice to the future outcomes. A future education workshop is planned by Council early in the new year to establish a roadmap on how to streamline and expedite the process.

Jannie Maritz: Future Education

SANIRE VISION, MISSION, & VALUES

Vision

To actively promote the South African rock engineering profession.

Values

- Honesty
- Integrity
- Professionalism
- Accountability
- Transparency

Mission

SANIRE promotes the advancement of the rock engineering discipline by encouraging and promoting:

- Interest and the development of education in rock engineering
- Professional practice and high ethical standards
- Networking, collaboration and information exchange
- Research areas

Name	Surname	Email	Branch
Louis	Lochner	Louis.lochner@Harmony.co.za	Free Vaal Branch
Ross	van Heerden	Ross.vanHeerden@Harmony.co.za	Gauteng Branch
Gunther	Betz	Gunther.Betz@norplats.co.za	Eastern Bushveld Branch
Gregory	Anton	anton@tshipi.co.za	Northern Cape Chairperson
Hlomani	Mthombeni	Hlomani.Mthombeni@sibanyestillwater.com	Western Bushveld
Nyandano	Netshivhazwaulu	Nyandano.netshivhazwaulu@seritiza.com	Coal Fields

NEW TICKET HOLDERS

Congratulations to all the new ticket holders, the mining industry is looking forward to the fresh ideas and strategies to achieve a zero fall of ground fatality goal.

Mashudu Ramathaga

Abraham Bentile

Hlomani Mthombeni

Wynand Van Wyk

Johannes Labuschagne

Easavani Wessels

Munyaradzi Musembwa

Jonathan Jakata

Mamokete Mokoena

ROCK STAR OF THE QUARTER

Full Name: Tinyiko Mhlanga

Company/Organisation: Thungela Resources

Designation: Strata Control Officer

Date and Place of Birth: 27 September 1996 -Limpopo, Giyani

Education: BSc in Mining Engineering (Wits)

First Job: Student Vacation Work

Philosophy of Life: "Do what you can with what you have"

Favourite Food/Drink: TPap with chicken Livers

Favourite Sport: Soccer (Kaizer Chiefs sadly)

Q. Where is your favorite hangout spot?

Ka-Nkovani

Q. What motivates you to get out of bed in the morning?

The few people who look up to me, more especially family and friends (I also look up to them)

Q. What is your favorite quote (why)?

"It's not the mountains we conquer, but ourselves" (Everything starts from just mere thoughts. What we constantly think about manifests and becomes the fate of our lives).

Q. What is your personal song (why)?

Nas ft Lauren Hill – Nobody (Given the chance to be in a foreign land where we are unknown, we could be our true selves.

Q. What is your favourite movie?

Shutter Island

Q. If the story of your life were to become a biopic, what would the title be?

"The Pursuit of Happiness"

Q. If the story of your life were to become a biopic, which famous actor or actress would play you?

O'Shea Jackson

Q. What is the best vacation you've been to or plan on going to?

Victoria Falls National Park

Q. Do you have a favourite newspaper, blog?

Twitter

Q. What is your favorite hobby?
Playing FIFA with the gents

Q. What is your greatest fear?

Dying without spending quality time with loved ones.

Q. What is your hidden talent?

I can play about seven keys on a piano even though some are rusty.

Q. What is the one thing that very few people know about you

I prefer spending my weekends indoors than going out.

Q. What's your most memorable facepalm moment?

My mom, going through my very first smart phone at the age of thirteen and if I remember very well, those were Mxit days.

Q. If you could interview one person (dead or alive) who would that be (why)?

Dr Evert Hoek (He contributed immensely to the fraternity of Rock Engineering.)

Q. If you could only drink one beer/cocktail for the rest of your life, what would it be?

Windhoek Draught

Q. If you were an animal, what would you be (why)?

I am inspired by the work ethics of ants. Small as they are, they are committed to collaboration and working as a team to achieve a common goal.

Q. If you were on death row, what would your last meal be?

Pap with chicken Livers

Q. What do you want to be remembered for?

Someone who was always willing to help others and more importantly my firm stand against any form of social injustice.

Q. If you were stuck on an island what three things would you bring?

A good quality camera to take good snaps of nature, a couple of books and a Knife.

Q. If you were a rockstar, what would your stage name be?

Tee Gee Eem

Q. Growing up, what was your dream career?

I just want to be Mining Engineer and had no clue about the niches within the field. I will forever be grateful to the people who introduced me to Geotech and contributed to my career.

Q. Why did you choose Rock Engineering as a career?

Curiosity, even today I get wowed by the process, systems and designs that have been built over the years in order to ensure that we do not only mine economically but do it safely as well.

Q. What are 3 words to describe Rock Engineering?

Design, monitor and reconcile.

Q. What do you find the most challenging of Rock Engineering?

Wea are dealing with “mother nature” and at times she just loses it.

Q. What do you like most about Rock Engineering?

It is such a broad field and the learning process will never stop.

Q. What are some areas that you believe will become of increasing importance in the near future of the rock engineering discipline?

The use of LiDAR technologies for ground monitoring and management of waste dumps and stockpiles.

Q. What is you view on the current spike on Fall of Ground Fatals over the past two years?

Complacency, routine work and high-risk tolerance.

Q. What solutions do you propose to reduce the Fall of Ground Fatals?

Awareness and we need more people on the ground to enforce compliance, meaning companies and agencies need to recruit and train more graduates to become Rock Engineers.

Q. Who is your role model/mentor?

My dad, Timothy Mhlanga.

Q. What is the best advice you have ever been given?

I was told to noy worry about the things I cannot change.

Q. What advice would you give to someone who want to choose Rock Engineering as career?

Rock Engineering is a very interesting field and in the initial stages of your lcareer, ensure that you spend more time on the ground (at the “face”) in order to understand the operator’s perspective so that you can bring practical solutions.

BRANCH MEETINGS

Coalfields Meeting

Gauteng Branch Year End Function

On a warm 3rd of December SANIRE Gauteng hosted their YEF at Kloofendal Nature Reserve. The day was kicked of by Dr. Steve Spottiswoode with a short presentation on the reserve and how gold was discovered in 1886. An interesting geological walk was enjoyed through the reserve where various geological complexities were observed. The walk also went to the very first place where gold was discovered with a short tour of the various audits that were mined all those years ago. The tour ended with well-deserved cooldrinks and snacks. A lovely day was had by all.

ORTLEPP AWARD WINNER

Establishing a testing criteria to relate the in-situ performance of static and dynamic capable mesh

J.P. Gouvea
Goldfields, South Africa

M. du Plessis
Goldfields, South Africa

ABSTRACT

Mesh based areal support is commonly applied in South-African deep-level gold mines. It forms part of an integrated support system that can cater for both rockfall and rockburst incidents. The application has been successfully applied over many years. Operations have different geotechnical conditions and practical considerations, which has led to the development of various types of mesh and integrated mesh-based support systems (i.e. meshing and lacing versus welded or chain-link mesh sheets). Typically rolls or sheets of mesh is pinned with rockbolts to the surface of an exposed excavation. Applications vary from hangingwall coverage in a conventional stope gully to complete excavation coverage in footwall drives of conventional mines or on-reef drives in massive mechanised mines. It is however critical to understand the behaviour of the rockmass and apply suitable support systems.

A study was conducted at a deep-level South African gold mine where seismic induced damage frequently requires the rehabilitation of the installed mesh-based support in drives. As traditional methods of determining dynamic support criteria did not prove to be useful, a series of small and large scale surface drop tests were conducted to simulate the observed seismic induced damage experienced by the mesh underground. Furthermore, the performance of different types of mesh were compared under similar and repeatable conditions. The paper describes the methodology followed. The preliminary learnings can be applied to environments where mesh is applied to combat either gravity induced rockfalls or seismically induced rockbursts.

Keywords

Areal Support, Surface Support, Mesh, Energy Absorption, Dynamic Loading, Static Loading.

INTRODUCTION

Mesh has been used as underground surface support since the early 1950's and consists of either woven (chain- link) or welded mesh sheets. Welded mesh is manufactured by welding a grid of crossing wires at their intersection points. Chain-link mesh is more flexible as it is manufactured by weaving a series of kinked wires into each other and knotting strands at its periphery.

Different experimental testing techniques are conducted throughout the mining industry to best characterise the performance of mesh. Despite some shortcomings in some of the testing methods, valuable insights are gained into the behaviour and performance of mesh subjected to dynamic and static loading.

It is critical to understand the rockmass behaviour to apply a suitable support system. More importantly, individual support elements (i.e. mesh or rockbolts) comprising a support system cannot be assessed in isolation. In many cases, there is a significant incompatibility between the mesh and rockbolts in terms of stiffness and strength. Support systems applied on most mines have been inherited over time or copied from mine to mine (e.g. 5.6 mm diameter welded mesh sheets). The actual rockmass behaviour and support system capabilities are not considered leading to further mismatches and ongoing underperformance of the support system. This may result in significant rockmass damage or instability, exposure to people or equipment and ongoing rehabilitation.

Although the traditional support design methodologies for both gravity and dynamic loading conditions (Ryder and Jager, 2002) were satisfied at the study site, significant support failure resulted during rockburst events. The testing methodology described in the paper was guided and informed by the actual underground observations of the rockmass and support behaviour at the study site.

BACKGROUND

In general, rockbolts control the overall stability of excavations by either reinforcing or suspending the surrounding rockmass (Ryder and Jager, 2002). Up to the mid 1970's, the application of mesh as ground support in South African mines was primarily to cater for static loading conditions. Different geotechnical conditions and practical considerations has led to deeper mining operations developing a need for mesh capable of withstanding dynamic loading conditions (e.g. seismicity and squeezing rock). As a result, chain-linked wire mesh incorporated with lacing rope (i.e. meshing and lacing) was applied with great success for many decades. The system allows for a significant benefit of load distribution between bolts using lacing rope. This application is however very time consuming, expensive and labour intensive.

A need arose for the application of a user friendly, static and dynamic capable mesh suitable for various environments. In the late 1990's to early 2000's, various trials were conducted to install areal support (mesh) in underground stope gullies, especially at seismically active mines. It was not until the late 2000's that mainstream companies (e.g. AngloGold Ashanti) adopted permanent in-stope gully mesh, known as welded mesh (refer to Figure 1).

The use of mesh evolved as the application at in-stope gullies and tunnels continued to show success. Temporary removable webbing / rope nets were subsequently introduced in shallow to intermediate narrow depth tabular platinum stopes as a leading practice in 2011 as a means of providing additional areal support along the stope face. At the time the testing of permanent blast resistant mesh applications were being developed. The successes of these permanent in-stope nets (mesh) were only realised around 2017 post successful underground trials (Pretorius, 2018). Of recent mines have started showing interest in adopting this leading practice with successful applications in both the gold and platinum industries.

Numerous experimental studies have been, and continue to be conducted throughout the world to design suitable mesh for underground support (Morton et al., 2007). Each research group apply different testing methodologies with varying loading and boundary conditions.

Figure 1. Welded mesh installed in a deep gold mine gully (left) and permanent blast resistant chain-link mesh installed in-stope on a narrow tabular platinum stope face (right)

ROCKMASS AND SUPPORT BEHAVIOUR

The study site is a deep level gold mine situated along the West Rand Goldfield on the north-western rim of the Witwatersrand Basin of South Africa. A fully mechanised, hybrid bord and pillar mining layout is used to facilitate long hole stoping (bulk mining) to extract a conglomerate package which varies between 20 m and 120 m in thickness. The advancing de-stress cuts are currently developed at approximately 2700 m below surface. Bords are 5.5 m high and 6 m wide, separated by 7 m wide crush pillars. This development (de-stress) footprint is mined horizontally, cross-cutting the various reef packages dipping at approximately 15 degrees. The excavations are supported with sheets of 5.6 mm welded mesh (referred to as mesh 4 later in the paper) pinned with high dynamic capable rockbolts (229 kN ultimate tensile strength, 53 kJ energy absorption capability and 230 mm yield capacity). The entire excavation is supported to a height of 0.5 m from the footwall. A layer of 50 mm thick 40 MPa fibre reinforced shotcrete (200 J capacity) is applied over the mesh along the shoulders of the excavation sidewalls as a secondary application lagging the advancing face by approximately 6 m.

A number of key behavioural trends were identified during rockfall and rockburst incidents:

- The magnitude of damaging seismic events ranged between M_L 0.5 and M_L 2.2
- Rockburst damage was limited to excavation sidewalls (refer to Figure 2)
- Some of the damaging events could be attributed to the intersection of problematic bedding planes with the damage concentrated below the bedding plane
- Rockburst damage was more severe where non-compliance to mine design was observed (e.g. pillar sizes)
- In some cases both the bolts and mesh were ejected from the excavations (Figure 2)

- Ejected rockbolts had a wavy appearance due to lock-up generated pre-ejection
- Mesh sheets failed at anchoring points with minimal to no yield activated on the rockbolts (Figure 3)
- Mesh sheets typically failed at overlaps
- Where shotcrete was applied over the mesh, damage was mostly contained. If shotcrete only partially covered the rockwall, mesh damage was more severe. If a problematic bedding plane was situated above the shotcrete, failure of the mesh would still occur (refer to Figure 4).

The behaviour of the mesh in these events could be used to benchmark the performance of the tests discussed in the following sections. The influence of shotcrete, mechanisms driving the rockmass behaviour and associated mine design consideration will not be discussed in this paper.

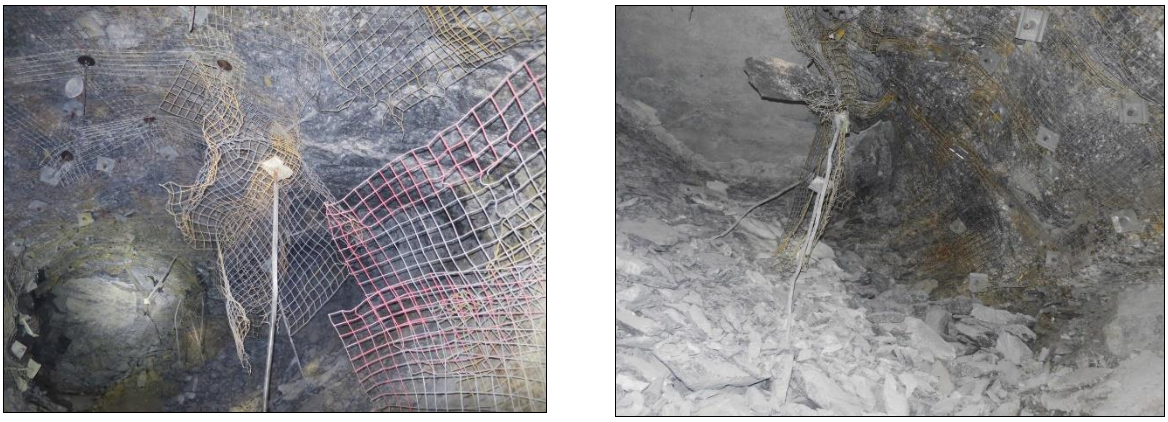


Figure 2. The photograph on the left shows damage following a ML 1.8 seismic event. Rockbolts and mesh failed when the right-hand sidewall ejected. The photograph on the right shows damage following a ML 0.7 event. Note the wavy appearance of the ejected bolts. The ejected rocks are from the left-hand sidewall. Notice the bedding plane along the hangingwall

Figure 3. The damage resulted from a ML 2.2 seismic event. Notice the inability of the system (rockbolt and mesh) to absorb the impact of the ejection. The stiff mesh folds around the bolt which did not engage the yielding mechanism

Figure 4. The photograph on the left shows sidewall mesh failure above the shotcrete following a ML 1.7 seismic event. The photograph on the right shows the ability of the shotcrete applied over the mesh to contain any potential sidewall damage following a ML 0.8 seismic event (right hand sidewall)

Some developments were made to address the behaviour of the faceplates and the overlap support. The initial faceplates consisted of a square 150 mm x 150 mm, 8 mm thick plate combined with 280 mm x 300 mm, 2 mm thick W-plate (also referred to as a combi-plate). Tests conducted on faceplates showed that a single 200 mm x 200 mm, 6 mm thick faceplate allowed for yield in the faceplate at reduced loads (the detail of these tests are not covered in this paper). This was more compatible with the ultimate tensile strength (UTS) of the rockbolts. The square faceplate was made round with winged edges to prevent the cutting of mesh strands and the W-plate was removed. These modifications to the faceplate configuration improved the behaviour of the support system and provided more effective areal coverage. A high impact, yielding push-on-plate was developed to eliminate the need to install a new line of bolts at mesh overlaps (after a face advance). This significantly reduced the stiffness at mesh overlaps and subsequently improved the effectiveness of the support system. The application of shotcrete was also extended to cover the entire sidewall to improve the damage containment ability of the ground support system.

MESH TESTS

Both small scale and large scale tests were conducted. The intent of the small scale tests were to replicate the underground behaviour and failures identified. Furthermore the tests were aimed at improving the understanding on how the individual components of the mesh or mesh / bolt interface effect the behaviour of the ground support system when subjected to both static and dynamic loading conditions. Once the performance limits were established, alternative meshes could also be tested under similar conditions. Ten different mesh types were subjected to static and dynamic loading conditions (refer to Table 1). The intent of the large scale tests were to test the mesh / bolt system under dynamic loading conditions.

Table 1. Details of the mesh sheets tested

		Mesh Type	Pattern	Strand Diameter (mm)	Mesh Aperture (mm)	Yield Stress (MPa)	UTS (MPa)
Mesh 1		Welded	Square (wrinkled)	4.0	100	728	787
Mesh 2		Woven	Diamond	4.0	50	219	542
Mesh 3		Woven	Diamond (with cable)	2.6	50	911	1 352
Mesh 4		Welded	Square	5.6	100	566	615
Mesh 5		Woven	Diamond	4.0	75	219	542
Mesh 6		Woven	Diamond	4.0	80	1 459	1 824
Mesh 7		Woven	Diamond (with cable)	3.0	80	1 812	1 983
Mesh 8		Welded	Square (with lacing)	5.6	100	568	609
Mesh 9		Welded	Square (double strand)	5.6	100	568	609
Mesh 10		Welded	Square (double strand)	5.6	100	594	621

Small scale static loading

Static loading tests were conducted at the CSIR using an 8896 kN Mohr and Federhaff compression testing machine. Mesh sheets were tested up to a deflection of 500mm. This was informed by the anticipated excavation deformation as measured from survey scanned data at the study site.

Mesh sheets were secured to the testing frame using four short bolts and faceplates spaced 1.5m apart on a square pattern (Figure 5). This also resembled the underground bolt spacing. The mesh sheets had no artificial constraints along its boundaries fixing it to the test rig. The tests were conducted in increments to mitigate equipment constraints potentially impacting on the tests results. This ensured that the loading of the mesh was accurately captured and loading effects of the test frame was avoided.

Five tests were conducted on each mesh type or configuration. A moving average line was fitted through each set of results to produce a 'best fit' line as shown by the results presented in Figures 6 – 8. The study site described in section 3 currently installs the standard 5.6 mm, 100 mm aperture welded mesh (mesh 4 as referred to hereinafter).

Figure 5. Static loading test rig. The photographs show the test set-up, loading of a mesh sheet with the pyramid plunger and the connection of the mesh sheets to the frame via the bolts

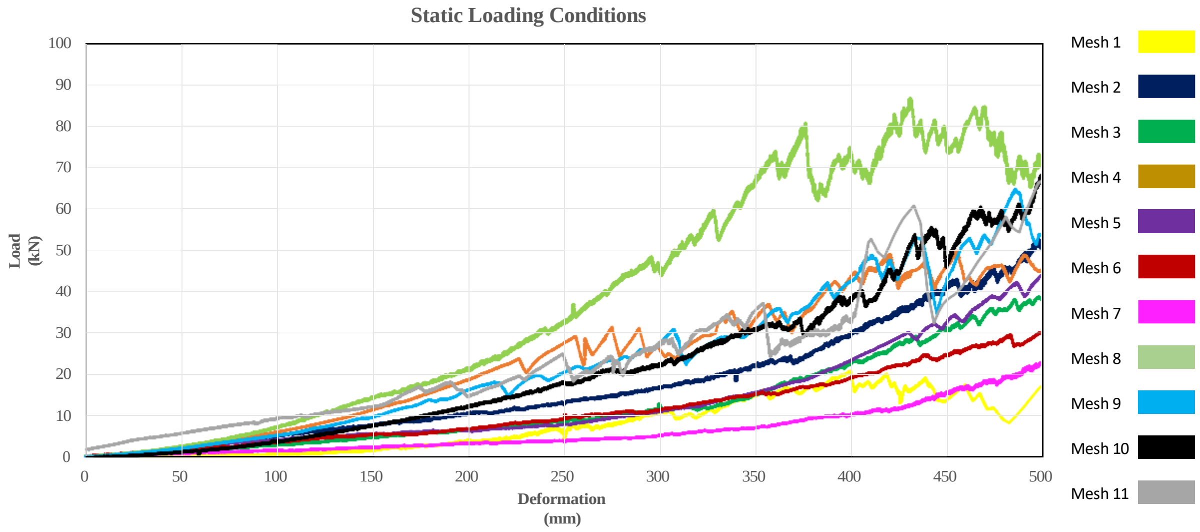


Figure 6. Results of the static loading tests conducted (all mesh types)

Red vertical lines were added onto Figure 7 and Figure 8 to illustrate the performance of the base welded mesh (mesh 4) at 250 mm and 500 mm on the load-deformation graph.

Welded mesh sheets

When subjected to 500 mm of static loading, double-stranded welded mesh sheets (also referred to as 'seismic mesh' after Whiting 2017), generated between 10 kN and 20 kN (20% - 40%) higher loads compared to a standard welded mesh sheets (mesh 9 and 10 compared to mesh 4). Double stranded mesh has additional strands welded along the perimeter aperture of the mesh sheet.

It should however be noted that the residual load bearing capacity between double-stranded welded mesh and standard welded mesh is comparable beyond 500 mm (not shown in the figures).

Welded mesh incorporated with lacing rope (mesh 8) generated the highest loads when subjected to 500 mm of static loading. It also had the highest stiffness. Loads generated at 500 mm of deformation were comparable to that of double stranded welded mesh sheets (mesh 9 and mesh 10), however the loads generated by the lacing rope exceeded that of double stranded welded mesh sheets beyond 500 mm (not shown in the figures).

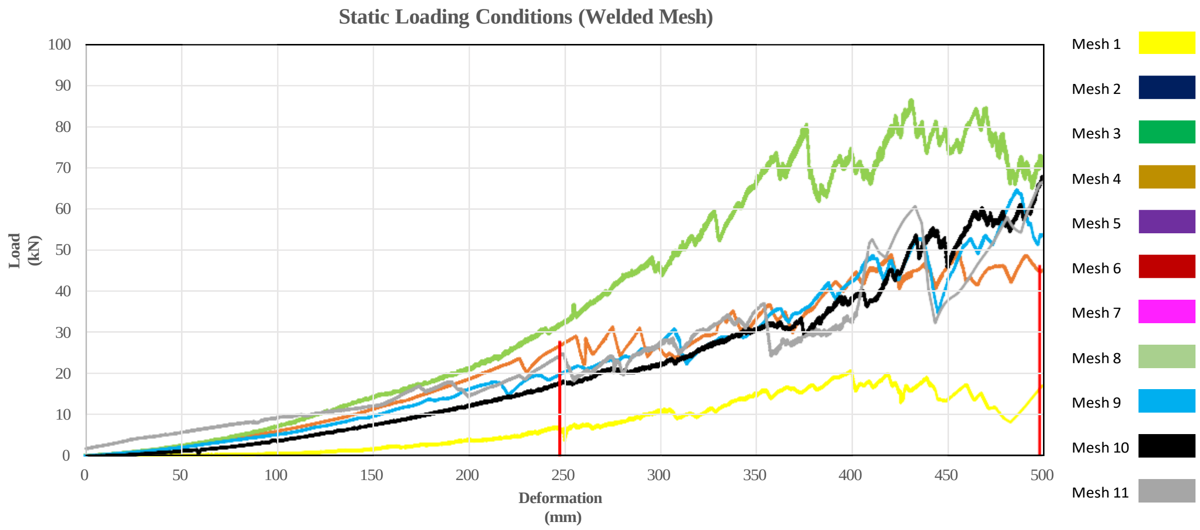


Figure 7. Static loading results (welded mesh types)

Chain-link (Woven) meshes

The overall mesh configuration impacted on the behaviour and performance of chain-link mesh. Increasing the strand thickness of the woven mesh sheets increases the stiffness (approximately 10 kN higher at 500 mm deformation). Also, decreasing the aperture size of the woven mesh sheets similarly increases the stiffness (approximately 15 kN higher at 500 mm deformation).

The advantages of using high tensile steel (mesh 6 and mesh 7) compared to mild steel (mesh 2 and mesh 5) could not be observed during static loading conditions. Other practical considerations should be considered in mesh selection, such as blast-on application, strand mobility and survival height.

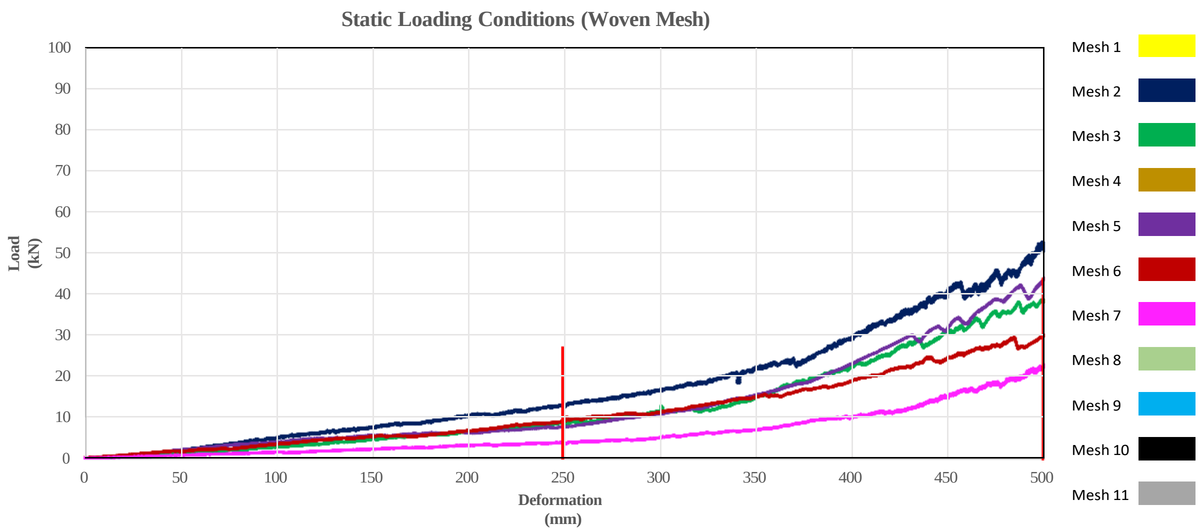


Figure 8. Static loading results (chain-link mesh types)

Small scale dynamic loading

Dynamic tests were conducted at the New Concept Mining (NCM) drop test facility in South Africa. Various iterations of tests were conducted to achieve the behaviour and failure of the mesh observed during underground site visits at the study site. This included:

- Experimenting with the impact footprints of the drop mass (large vs small)
- Impact location of the drop mass (directly between or across rockbolts). This impacted on the mesh stiffness, performance and behaviour
- Varying the mass of the object being dropped (450 kg vs 800 kg vs 1 t vs 2 t)
- Varying the configuration of the drop mass sample (un-reinforced vs reinforced plates). Unreinforced plates allowed for movement and recoil when the mesh was impacted, affecting the behaviour of the mesh
- Varying drop heights (ranging from 0 mm to 1400 mm) to achieve the required impact energy (ranging from 2 kJ to 6 kJ)
- Dropping on cellular lightweight concrete blocks, compared to dropping directly on mesh to simulate a fractured rockmass striking the mesh.

The most representative behaviour was achieved using a 1 t mass dropped from 410 mm (4 kJ impact energy). The mesh was secured to the test frame using 4 bolts spaced 1.5 m apart in a square pattern. The mass was dropped onto cellular lightweight concrete blocks and not directly onto the mesh.

A review of large scale field drop test results that was conducted at the Savuka drop test facility in South Africa (Ortlepp and Stacey, 1997), indicated that a 4 kJ impact energy was along the upper limit for welded mesh sheets (refer to Figure 9). This verified the output achieved at the NCM test facility where the intent was to replicate the mesh behaviour observed at the study site.

Once the test setup was finalised, variations of mesh sheets and configurations could be tested in a repeatable and comparable manner. The test set-up is shown in Figure 10. As a first phase, visual tests were conducted without any instrumentation to ensure that the different mesh sheets considered were able to successfully resist the 4 kJ impact drop. This prevented potentially damaging monitoring equipment during failed attempts. Mesh sheets that failed during the visual tests were not considered for any further testing. 70% of the mesh sheets tested passed the visual drop tests.

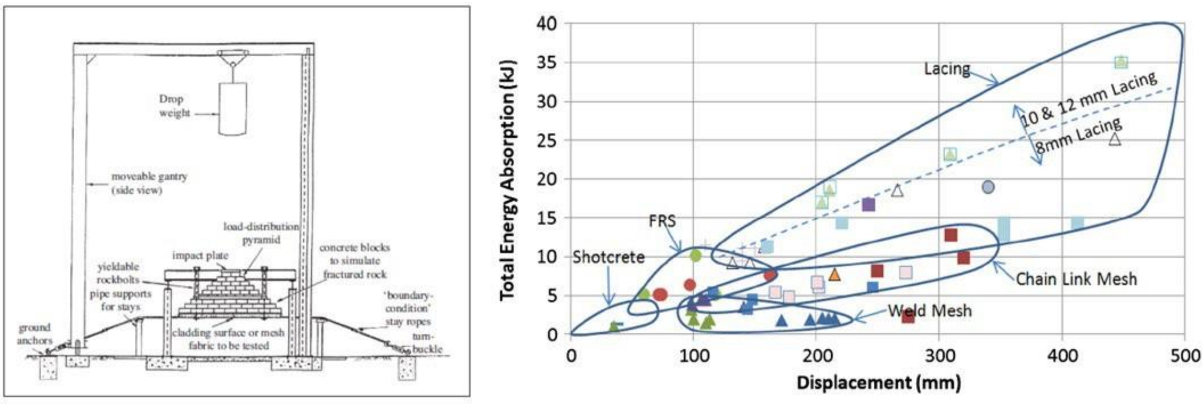


Figure 9. Compilation of drop tests performed on various surface support elements after Ortlepp and Stacey (1997)

Figure 10. The dynamic test set up at the NCM drop test facility. A 1 tonne mass was dropped on the cellular lightweight concrete blocks to achieve a 4 kJ impact energy. The mesh was secured to the frame with bolts spaced 1.5 m apart in a square pattern

The results of the dynamic tests conducted are shown in Figure 11. The double-stranded welded mesh sheets (mesh 9 and mesh 10) arrested the dropped mass at 35% lower deflection (200 mm) compared standard welded mesh sheets (mesh 4). Visually, it could be observed that the energy absorption limit between single- and double- stranded welded mesh sheets were comparatively similar as the shear strength on welded strands were the same.

Increasing the thickness of woven mesh strands (mesh 7 compared to mesh 6) reduced the amount of deflection experienced by the mesh by 220 mm (30%). Incorporating lacing or steel ropes along the perimeter of mesh sheets (woven or welded) reduced the amount of deflection by approximately 40%. Typically a steel rope is added to some mesh types to improve its ability to resist the blast impact close to the advancing face (i.e. mesh 6).

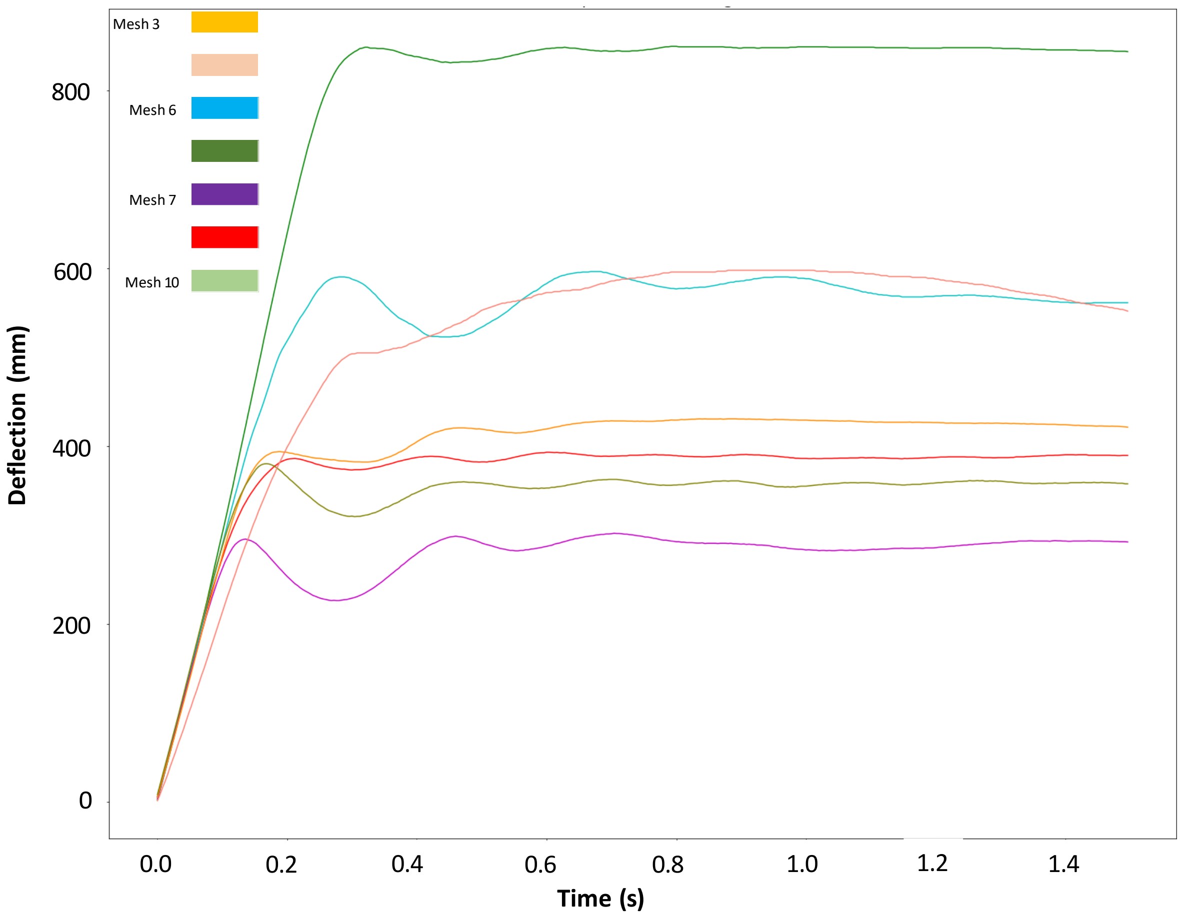


Figure 11. Dynamic loading results (all mesh types)

An important learning from the small scale dynamic tests was regarding the behaviour of the mesh at the rockbolt / faceplate interface. During the initial test set-up the mesh was clamped to the frame using a single faceplate which was tensioned with a nut (refer to Figure 12). The observed failure of the mesh was at mesh strands directly adjacent to connection points. At these locations the mesh strands experience higher transversal loading against the rockbolt, The benefit of the faceplate was therefore insignificant. This resulted in the mesh failing prematurely (25% of its typical capacity). A double faceplate was added to the test set-up to simulate a mesh tightly clamped against an excavation rock surface (refer to Figure 12). The results achieved from this configuration was comparable to other industry results (100% of its typical capacity). The double faceplate configuration ensured that transversal loading was limited and the performance of the mesh was reliant on numerous strands interacting with the faceplate.

Figure 12. The photograph on the left indicates the premature failure of mesh strands as loading takes place against the rockbolt rather than the faceplate (single faceplate set up). The photograph on the right indicates good interaction between the faceplate and mesh (double faceplate set up). The transversal loading was limited and the performance of the mesh was reliant on numerous strands interacting with the faceplate

The output of this finding gave insight to the behaviour of mesh when installed tightly against an excavation rock surface versus where the faceplate was loose. This confirmed the observations from underground investigations (Figure 13 and Figure 14). A poorly installed mesh sheet (faceplate not pushed flush against the rockwall) would significantly underperform irrespective of its capability (Figure 14). The only way this may be circumvented is to add a perimeter cable to a mesh sheet to prevent the premature failure of individual mesh strands along the unconfined anchor point. Transversal loading forces will be transferred to the perimeter cable rather than the weaker individual strands or welds. Yielding in the cable system should be considered to ensure the mesh engages and interacts with the rockbolts at the anchor points. This was also an observation from tests conducted by Ortlepp and Stacey (1997). Ortlepp and Stacey identified the initiation of mesh failure at the faceplate, but believed that this could have been improved by the improved design of the faceplate. The findings from the tests conducted by the authors therefore further contribute to our understanding why failure is occurring at the faceplate locations which can be attributed to poor contact between the faceplate and the rock surface.

Figure 13. Good faceplate contact. The photograph on the right shows how the mesh engages the bolt as it wraps around the faceplate

Figure 14. Poor faceplate contact resulting in the failure of the mesh strands as it loaded laterally against the rockbolt

Large scale dynamic tests

The intent of the large scale dynamic tests were to test the integrated bolt-mesh system to obtain the dynamic response of the complete ground support system. The test rig used is situated in Walenstadt, Switzerland. This facility formed part of the rockburst research and development project supported by the Codelco mining company in 2016 (refer to Saner and Murri, 2016).

The test rig consists of a platform with two-levels of square-shaped pyramidal trunk geometries (refer to Figure 15). The square frame at the bottom of the rig has dimensions of 3.6 m x 3.6 m where different support systems can be constructed. A 6400 kg concrete block is dropped from a pre-determined height to achieve a desired impact energy and force. The concrete block is situated along and slides over the centre bolt. Rockbolts can be spaced at any desired spacing along the test area. Depending on the bolt mechanism and length, special attachment points are made up to allow the bolt to function in the required manner. This can comprise steel tubing or a representative casted medium such as grout or resin. A pile of crushed rock is placed on top of the support elements (to simulate a fractured rockmass) where the concrete block would eventually impact (refer to Figure 16). Load cells, high speed cameras and accelerometers are utilised to quantify the behaviour of individual support elements and the overall support system.

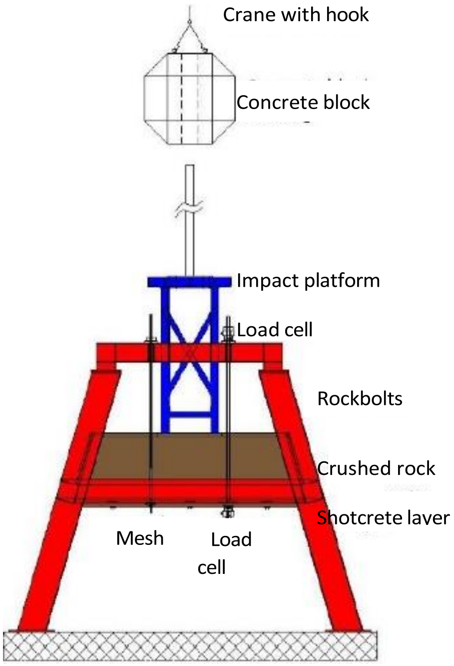


Figure 15. Setup of large scale dynamic test rig

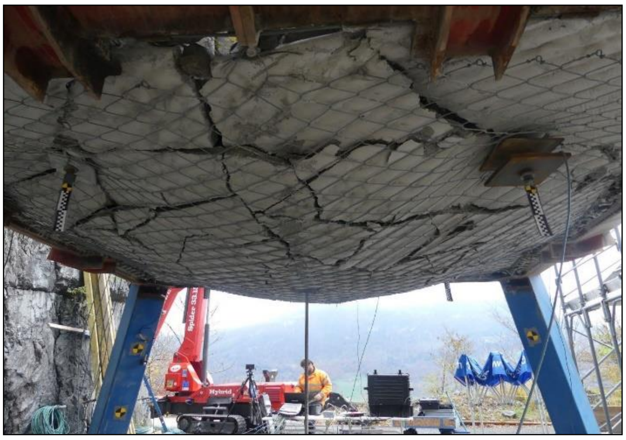
Figure 16. Large scale drop test facility in Walenstadt, Switzerland

The initial test was set up to represent the observations at the study site and to establish the various test parameters and configurations. High impact, yielding rockbolts were spaced on a 1.5 m square pattern. A 4 mm chain-link mesh (mesh 6) was fixed to the rig with a perimeter cable. The concrete block was dropped to achieve an 80 kJ impact energy.

During the first test, the bolt in the centre of the system remained intact as the concrete block did not properly impact the faceplate. As a result, the yielding components on the bolt did not activate. The mesh failed prematurely around the centre bolt resulting in the complete failure of the mesh sheet. It was also noted that the chain-link mesh tested could only elongate in one direction due to its inherent design.

A second simulation was repeated with a perimeter cable added only at the 2 opposing ends of the mesh which could not elongate. This would ensure that the mesh behaviour was not limited to the strength of individual strands along this dimension. The two open ends were connected to an attachment point along the centre of the rig perimeter. This simulated another two bolt anchoring points and formed part of the 1.5 m support spacing pattern (refer to figure 17). A larger impact plate was added to the centre bolt. This was to transfer load from the impacted surface to the centre bolt. As the yield is activated on the bolt, the system would absorb a large amount of the kinetic energy, allowing the mesh to contain the impact. During the second test, the centre bolt did eventually exceed its yield capacity and snapped, but the mesh did not fail. This result provided valuable insights for future testing, especially involving woven mesh sheets.

Further tests planned will firstly aim to replicate and benchmark the underground behaviour and failures identified at the study site. Different support configurations will then be constructed and tested. Test setups will consist of varying mesh types, rockbolts, shotcrete and combinations thereof. Options will also consider the placement of the shotcrete layer either below, above or casting it inside the mesh sheets. The intent is to improve the understanding of the complete ground support system, if the large scale dynamic surface tests can be compared to actual underground behaviour and be able to compare various support options to one another in a repeatable and comparable manner.



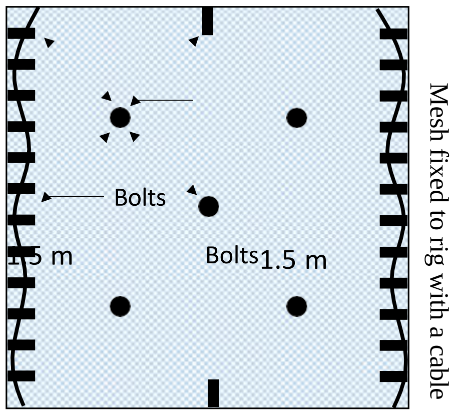


Figure 17. Photograph (left) below the rig showing the behaviour of the mesh post the impact. The mesh engaged the centre bolt, achieving maximum yield before failure. The mesh did not fail with the second line of bolts still intact. The diagram on the right illustrates the mesh and bolt configuration

CONCLUSIONS

Small and large scale static and dynamic tests were conducted to relate the observed seismic induced damage experienced by mesh based support underground. Once the performance limits were established, alternative meshes could also be tested under similar and repeatable conditions. The test results provided valuable insight into the behaviour and performance characteristics of mesh, both individually and as part of a support system. The application of a mesh based support system must be fit for purpose and accommodate the mechanisms driving rockmass instability. The environment where the mesh will be used must be considered when selecting an appropriate mesh type or configuration. Where the applicable mesh is used as an additional areal support along the hangingwall of a stope face in a narrow tabular environment, blast resistance, arresting distance and survival height will be critical. Furthermore, the mesh will need to cater for the potential fall of ground magnitude which may result between installed support elements. Where the mesh is planned to be installed in a high stress mechanised environment such as the study site, woven mesh may present improved behaviour, but the rockmass will quickly unravel behind the mesh giving it a baggy appearance between installed bolts or perimeter lacing configurations. This may restrict equipment maneuverability as it will impact on the excavation dimensions. The test results also highlighted how the mismatch in the performance of individual support elements in a ground support system may lead to the premature failure of the support system and inability to contain rockmass instability. The preliminary findings can be applied to environments where mesh is installed to combat either gravity induced rockfalls or seismically induced rockbursts. It should empower industry practitioners through an improved understanding of the parameters influencing the overall mesh behaviour.

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REFERENCES

Morton, E.C., Thompson, A.G and Villaescusa, E., 2007. Testing and analysis of steel wire mesh for mining application of rock surface support. *Proc. 11th ISRM Congress*. Portugal.

Ortlepp, W.D., Stacey, T.R., 1997. Testing of tunnel support: Dynamic load testing of rock support containment. *SIMRAC GAP Project 221,* South Africa.

Pretorius, M, 2018. The successful extraction and beneficiation of the UGS split reef. *Proc. ARMS 10.* Singapore.

Ryder, J.A. and Jager A.J., 2002. A textbook on Rock Mechanics for Tabular Hard Rock Mines*, SIMRAC.* Johannesburg.

Saner, A., and Murri, R., 2016. Testing of the Rockburst Codelco Setup S3-S5, Report No. *Psi-16-1231, DTC*, Vauffelin/ Biel, Switzerland.

Whiting, R.K., 2017. In situ static performance assessment of mine mesh. *Proceedings of the Eighth International Conference on Deep and High Stress Mining*, Australian Centre for Geomechanics, Perth, pp. 747-762.

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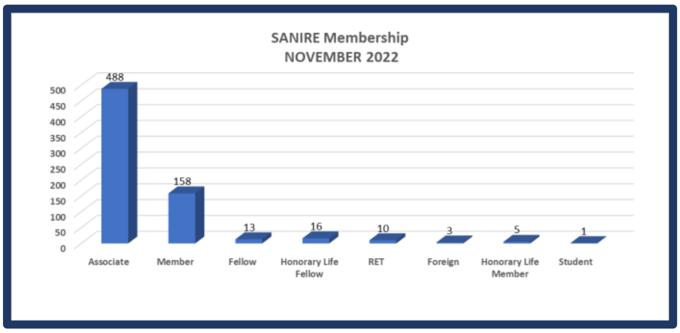

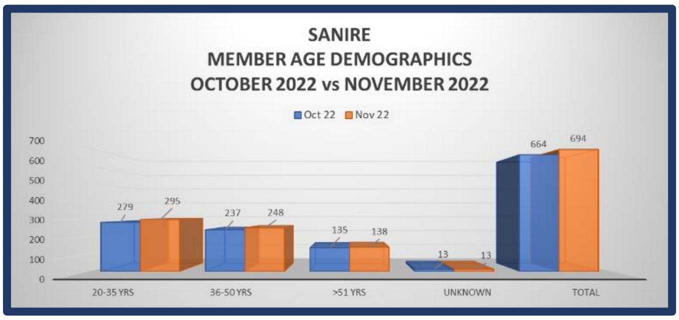

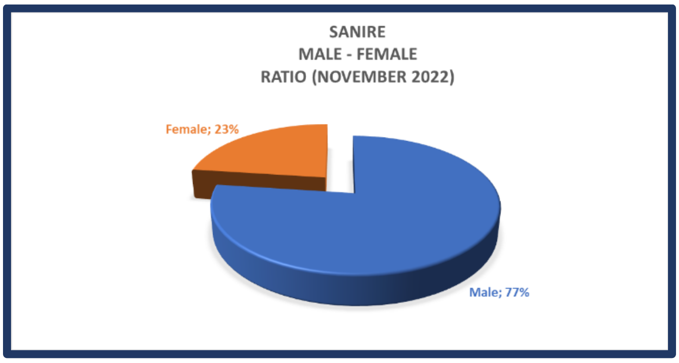

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Mbalenhle Buthelezi
Association Secretary
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l: mbalenhleb@mpas.org.za | info@sanire.co.za
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