ROCK REPORT

Mechanics & Tunnelling

IRMT

RMT

NAWI Graz
GEOZENTRUM

TU Graz
Graz University of Technology

MLGT
Machine Learning in Geotechnics

Content

Marcher's Column

How did our students experience the time of the COVID-19-lockdown? What positive and negative experiences could be gathered during this time? To answer this question, this RockReport 2 contains interviews that are well worth reading. In the last quarter we also welcomed two guest speakers in an online platform. Both lectures were attended with great interest: 70 participants and 40 participants respectively attended the Thursday lecture series in this form.

I am also pleased that 3 weeks ago we were able to carry out the "technical acceptance" of our new soft rock triaxial equipment at the factory in Germany. With this we are investing massively in one of our future research directions of the institute. "Moving forward" is our motto and we are tackling this with an enlarged team. Besides the Lab News there are also news in the research field of rockburst and long-term observation of tunnel linings (Smart Tunnel Linings).

Have fun reading the Rock Report, "Glück Auf" from Graz!

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Research Overview

Smart Tunnel Linings - STUNNING

Those to whom we could introduce our institute with a presentation since the end of 2018 might remember two of the visions we are working towards: smart data processing or smart dust, and online limit state assessments of tunnels. Although one can already picture the visionary scenarios reading these catchy phrases, let us describe them briefly.

The integrity of (innermost) tunnel linings must be guaranteed over the entire service lifetime. In general, once the tunnel is built and in use, the condition of the tunnel gets checked periodically for example by visual observations (e.g. damages visible at the lining surface like cracks and spallings), destructive or non-destructive examinations at selected locations, or displacement measurements. In case of the latter, advances in technology allow to catch the displacement characteristics of the liner with a high resolution (e.g. laser scanning). However, with most approaches the actual condition of the inside of the lining either can be assessed locally only or needs to be deduced from measurements and observations from outside. Such measurements and observations interfere with the operation of the tunnel, causing additional costs for the operator. And normally the operators like to have their tunnels undamaged 😃, what makes the assessment even more difficult as there would be nothing or not much to observe at the inner surface of the lining even though the utilization of the lining might be relatively high.

But we believe that in a few years or decades it will be possible to assess the condition of a lining on a large scale by adding tiny sensors to the concrete mixture with which physical quantities can be measured anytime the operator likes to. Having the sensors distributed along the entire circumference of one lining segment and along the entire stretch of the tunnel allows to assess the lining condition in its entirety. And if we can manage to elaborate a routine to evaluate the measurement data automatically (for example with the help of Artificial Intelligence), it might be possible to assess the state of the lining online and (more or less) in real-time.

With the research project termed STUNNING, we start our contribution to realize this vision. The installation of such a large number of sensors requires the sensors to be free of any cables, otherwise the installation effort would be far too high. And there are sensors on the market for which it seems that they meet our demands. Energy transfer from the receiver to the sensor (to perform the measurement) and data transfer from the sensor to the receiver (to read the recordings) are possible in a wireless way, also if the sensor is implemented within concrete. The quantity to be recorded by the sensors can be, for example, the moisture, the temperature, the strain, or–if the technology develops fast–the stress. At a first step, we investigate the functionality of the system on small-scale experiments. If the application is successful and factors influencing the results the most could be identified, investigations will be continued at large-scale experiments. At later stages, investigations focus on the feasibility to add these sensors to the concrete mixture, on the automatic localisation of the sensors within the cast-in-place liner in space, and on the automatic evaluation of the recorded data.

We proudly announce that the Austrian Society for Construction Technology (öbv) supports our project. By the end of this year we want to apply for a funding by the Austrian Research Promotion Agency (FFG) for which we still need collaboration partners. If you believe that the above-mentioned vision will not stay a vision in tunnelling, and if you want to join our research consortium, don't hesitate and contact us. We'd be happy to corporate with you.

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Research Focus Today

Rockburst

Predicting the behavior of rock mass is of utmost importance in tunnelling and mining. Only if the potential failure mechanisms of rock and rock mass are well understood, failure can be foreseen and avoided and the consequences reduced, respectively. Rockburst is particularly problematic because the rock mass fails abruptly and rapidly releases high amounts of energy. It therefore represents a major safety risk to workers and equipment in tunneling and mining. As projects advance to deeper areas, rockbursts will occur more frequently and its prediction will gain in importance.

The Institute of Rock Mechanics and Tunnelling does already research on rockburst for several years. This spring, the institute successfully completed a 3-year research project funded by the Austrian Research Promotion Agency (FFG). The Institute of Rock Mechanics and Tunnelling led the project in cooperation with the Veitsch Radex GmbH & Co OG, the Institute of Applied Geosciences (Graz University of Technology) and the Interfaculty Department of Geoinformatics (University of Salzburg). Additionally, the Jackson School of Geosciences (University of Texas, USA) was involved as an international partner.

The nationally funded research project presents a multidisciplinary approach to investigate the influence of (micro-) mechanical and (micro-) structural characteristics and their individual effect on brittle rock failure, especially rockburst. The research is based on a laboratory program using state-of-the-art rock mechanical testing, acoustic emission testing, micro-computer-tomography, object based image analysis (OBIA) and geostatistics. In addition to rock types typical for rockburst, also artificial samples were tested. The use of artificially produced materials ensured the reproducibility of tests under controlled conditions. Embedded in this project is also Angelika Klammer's doctoral thesis, which compiles and analyses the findings, enhancing the knowledge further. The results allow a better understanding of the underlying mechanism of rockburst and underline the usefulness of petrographic information within rockburst risk analysis.

With this better understanding of the mechanisms, the aim for future research is to extend this knowledge by using different sensor technologies for acoustic emission testing and to put the gained knowledge into practice by implementing it into in-situ-monitoring. For the development of new fibre optic based sensors the Institute of Rock Mechanics and Tunnelling is cooperating with the Scuola universitaria professionale della Svizzera italiana (SUPSI) from Switzerland. For in-situ applications, cooperations with sites around the world, that have experienced major rockbursts, are in planning. Lukas Gottsbacher is doing his doctoral thesis within this research project. This research will refine currently used rockburst risk assessment. Hence, it will contribute to reduce the safety risk to workers and equipment in tunnelling and mining.

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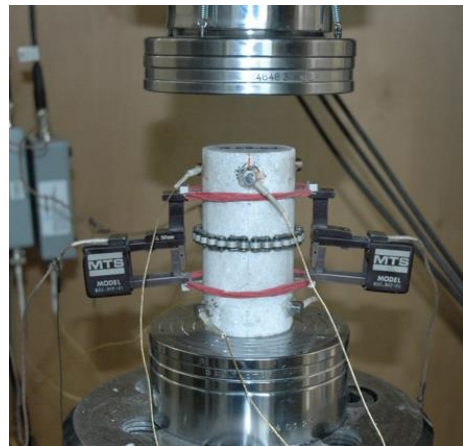
Recent RMT Guests

G. Grömer

© ÖWF/Zanella

Initiated by our staff member Georg H. Erharter, who often looks out of the box and in all directions, RMT established a cooperation with the Austrian Space Forum (ÖWF) and with its administrative director Dr. Gernot Grömer. Dr. Grömer is a visionary—as we see ourselves too—and brings operations intended to be performed in future on other planets of this galaxy down to the most surreal places on earth. And with him and the ÖWF we might be a part of such an operation soon, contributing to site investigation scenarios for Martian rocks and the Martian underground. To foster our relationship, we planned a guest lecture by Dr. Grömer on March 19th, 2020, together with the alumni network of Graz University of Technology, alumniTUGraz 1887. Unfortunately, because of the development of COVID-19 crisis we had to cancel the event. However, on June 25th, 2020, we could organise the guest lecture virtually (i.e. online). 40 friends and colleagues from Austria, Germany and Switzerland took part in the online lecture "Expedition Mars" and in the discussion afterwards. It was a full success. Thank you Dr. Grömer!

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M. Krautblatter

It was a great pleasure for us that so many colleagues and friends from different countries (Austria, Germany, Switzerland and South Tyrol) participated in the online lecture of Prof. Michael Krautblatter with the title: "Ein Fels-Eis-mechanisches Modell für die Destabilisierung von Permafrostfelsen: Laborversuche, geophysikalische Feldmessungen und Modellierung". Besides the very successful presentation itself, our moderator Alexander Kluckner was able to initiate a lively discussion afterwards. With >70 participants, it became clear that the format of an online presentation could bring a change to the time of the Corona lockdown. However, we also believe that this format offers the possibility to participate in a lecture in the series of our "Donnerstag 17 Uhr Vortragsreihe" of the Faculty of Civil Engineering at Graz University of Technology without having to pay for travel and accommodation. Considerations for such online participation are currently under development.

https://www.tum.de/nc/die-tum/aktuelles/pressemitteilungen/details/34809/

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Lab News

Technical acceptance of the new hard soil / soft rock triaxial equipment at GL-systems (Germany)

One of our main research topics for the future will be Hard Soil / Soft Rock Mechanics including new approaches for testing and modelling. In hard rock testing pore water conditions are neither controlled nor measured. The loading is applied fast and the applied stresses are much higher compared to soils. Oil is used instead of water for filling the cell to generate the confining pressure. As the behaviour of hard soil / soft rock is in between soils and rocks, the testing equipment must consider aspects of both, soil and rock testing. The testing equipment must be able to apply loads extremely slowly and also it must allow control over the pore water pressure conditions.

We decided in 2018 to order such a special triaxial testing equipment. Visits to the university laboratories in Torino, Zürich and Aachen provided experiences of researchers with such special testing equipment and helped us to specify the components in a correct and successful way. It took a while to get the components of the testing equipment to be built from a specialized company in Germany. After delay due to the Corona lockdown we could execute the technical acceptance at the factory in Germany (GL-systems) June 8th and 9th 2020.

We are looking forward to get this new triaxial test equipment to be installed in our laboratory at the end of July 2020. We will report on the first calibration and validation tests soon!

- force: ± 300 kN,
- max. confining stress: 30 MPa
- max. pore water pressure: 10 MPa
- test speed: 0.015 µm/min - 20 mm/min
- sample diameter: 50 – 100 mm
- total weight: ~ 1300 kg

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COVID19 – a student's perspective

If someone had told me a year ago that our urban appearance would be unthinkable without a protective mask, as in the Asian region, I would have declared him to be crazy. But this shows how naive we humans are! At the beginning of February I was in Japan, at that time a real Corona Hot-Spot, but even there I still smiled at the protective masks and thankfully rejected them.

When the situation in Europe worsened and both schools and universities were closed, I still could not really guess the extent of the problem. Optimistically I adjusted to 2-3 weeks of climbing combined with home office. However, the tide suddenly turned with the increasing number of cases and within a few days uncertainty spread! What will the semester be like? Can I take exams? What will happen with my bachelor thesis? Just to quote a few thoughts from that time.

A few weeks later I am now sitting in my childhood bedroom in front of the computer and follow online lectures. Everyone was talking about deceleration at that time and somehow this was true, I rarely spent so much time with my parents and my sister and in retrospect I am also grateful for these moments. Because without "lock down" the "Lagerhaus" (an Austrian warehouse for gardening) would certainly not have been able to reach these sales figures and I would not have improved my skills with the chainsaw (Georg smiled).

It was also admirable how quickly professors followed the government's guidelines and made online teaching possible in no time at all. The spectrum ranged from Skype lectures, over commented Power Points to elaborately produced videos. Here, too, the adage that every crisis also holds a chance is true. Just as many working people no longer want to do without their home office, I too got used to the lecture videos. Personally, I think that this method of lecturing does not have to be limited to crises, but should also be promoted more in regular university operations. This lecture method could make life a lot easier for students who have to commute to Graz or who do not have the luxury of living in near to the university.

Georg Kaml – Bachelor's programme Geosciences
Interview led by T. Geisler (geisler@tugraz.at)

COVID19 – a student's perspective

At the end of February I set off again to Graz. There I had to prepare for my exams, study together and write my exams. The normal everyday life at the university that you like to complain about. Of course I also actively followed the reports on the situation in Italy. And I never thought that it would happen like that here, too. But suddenly there it was, the standstill. A life without the usual daily routine, limited to your own home. That was initially a stressful situation for me. Again and again the question: What is going to happen now? But time passed and you got used to the new situation. I remembered old hobbies and tried to keep myself busy somehow. Faster than expected, the university also returned to life, even in my own apartment. Distance learning picked up full speed. A new experience for teachers and students.

After some initial difficulties in the beginning, distance learning worked really well in some cases. Our professors were also very cooperative. I felt that examinations, which were now increasingly held orally, were good practice.

The crisis has taught me a lot, especially in terms of ability to work independently and self-reflection. But now I am really happy to return to my usual everyday life and to see familiar faces again regularly. The shared beer after a day of learning tastes better than ever. Let's hope that the longed-for return to normality does not mean discarding all the good intentions that were made.

Michael Kienzl – Bachelor's programme Geosciences
**Interview led by T. Geisler (geisler@tugraz.at)**

Site Reports

HSSR – detection of shear zones using CPT tests

As reported in the last Rock Report (2020/01), three testing campaigns were conducted at the construction site of the Fürstenfelder Schnellstraße S7 in cooperation with Asfinag. The goal was to explore the limits of conventional CPT devices in hard soil layers. In addition to the conventional CPT setup, several measures were administered to ease the ground penetration such as friction reducers, lubrication and different tip geometries. Although there were minor setbacks and problems to overcome due to the permanent sounding at the absolute limit, the results are promising and have been collected and evaluated in a Master's Thesis. This work should form the basis for further research regarding in situ testing methods on hard soils or soft rocks (Master's Thesis M. Harmuth).

Furthermore, first CPTs were carried out in an area were existing shear zones have been already detected. The goal of the CPT tests was to determine its slip surface. Such a detection of shear zones would be beneficial due to its fast and cost-efficient applicability.

It is our intention to perform additional testing campaigns to analyse and interpret CPT data in relation to the detection of shear surfaces at sites with historical slope instabilities.
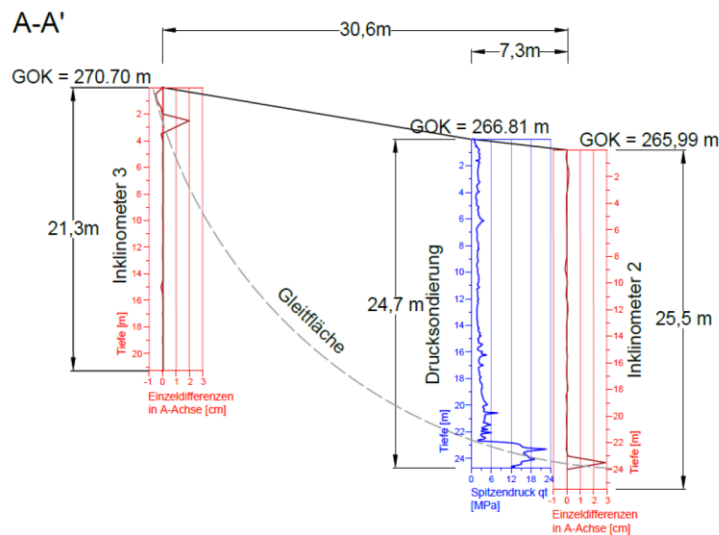
Example of a CPT test to detect shear zones verified by inclinometers (Master's Thesis M. Harmuth, 2020)

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Publications & Presentations

All publications of the institute are listed chronologically on our underlinehomepage. Selected papers and presentations are presented here.

MSAC: Towards data driven system behavior classification for TBM tunneling

*Erharter, G.H.; Marcher, T. (Tunnelling and Underground Space Technologies)* Open Access

https://doi.org/10.1016/j.tust.2020.103466

Rockmass classification systems are an integral part of today's geotechnical design process. Many of these classification systems are however based on subjective or semiquantitative assessments which leads to a call for more objective classification systems.

One way to achieve this goal in mechanized (TBM) tunneling is to use the TBM operational data – or computed parameters thereof - as a basis to decide whether or not "regular advance" is at hand. We support this data driven approach by presenting MSAC (Multivariate sequence Segmentation, Abstraction and Classification) which is a computational framework that [...]

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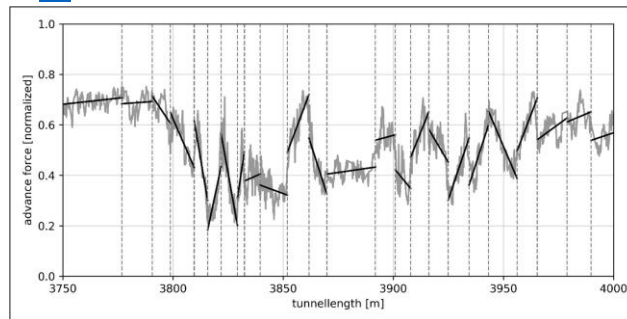
Investigation of geotechnical interfaces for Building Information Modelling in Tunnelling

L. Gottsbacher, S. Stauder und T. Marcher (World Tunnel Congress 2020 – to be published)

Digitalisation is now an essential part in the construction industry. One of the latest and most innovative feature in this field is Building Information Modelling (BIM). BIM in tunnelling and geotechnical engineering differs significantly from structural engineering, as the geology has an important impact. This paper shows different approaches on how to create interfaces between 3D geological models, 3D geotechnical codes and numerical codes as well as their compatibility with a BIM model. For this two methods are investigated with different software packages. A clear workflow on how to achieve an automatized import between the models is shown. In addition, a method to generate a code to create a fully automatized optimization model is discussed in the paper.
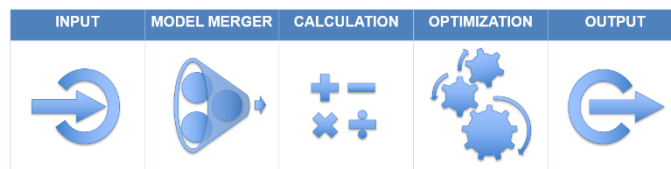
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Faces

Markus Harmuth

My decision to study civil engineering was based on my general fascination for creating buildings and structures. A further factor for me was the interaction of many different disciplines in this field and the multitude of professional perspectives that result. Relatively soon during my bachelor's degree I decided to specialize in geotechnics and therefore started to study the master for Geotechnical and Hydraulic engineering with a focus on tunneling. Visiting the construction sites of the Koralm- and the Semmering-Base-Tunnel as well as my professional activity for the ÖBB Infrastructure corroborated me in the choice of my studies. Recently I was able to finish my master thesis about cone penetration testing in Hard Soil - Soft Rock areas and I am already looking forward to new geotechnical challenges in my future career.

Juan Davila Mendez

The family business got me close to multiple infrastructure projects ever since I can remember, allowing me to visit and, eventually, work at important sites that gave me a gasp of what later on will become an important part of my life. After completing my civil engineering studies in my home town (Bogota-Colombia) and working for 2 years as a tunnel supervisor and geotechnical designer, I landed in Graz where I would live for more than 8 years and complete my masters and doctoral degree. My years in Austria were extremely enriching. Not only from an academic point of view but also from a personal one. Being able to interact with people who have a different way of thinking, a sense of diversity formed that I believe makes us into more tolerant human beings. From the professional and academic point of view, I have lots to thank to the institute, and to the professors and colleagues that I worked with; the acquired knowledge prepared me for the challenges that I now face as a designer and consultant in multiple projects in Colombia. I am also currently teaching Tunneling engineering at the university and was a coauthor of the tunneling manual for Colombia.

Faruk IŞKIN

My journey with the Institute of Rock Mechanics and Tunneling began in summer 2019 when I did my internship there. I was lucky enough to be involved in a few special ongoing research topics (e.g. Triaxial test simulation, production of artificial rock samples including a feasibility study on the utilization of 3D printing methods in this field). The joyful and informative challenges with which we coped during these studies aroused my curiosity in the topic of rock mechanics. Recently, I have completed my master's thesis which covers the anisotropic evaluation of laboratory testing results from tests performed on quartz phyllite in a cooperation with the Institute of Rock Mechanics and Tunnelling and Budapest University of Technology and Economics. In the future, my desire is to contribute to the development of cutting-edge solutions in the field of rock mechanics and tunneling and thereby helping to improve the methods and approaches adopted for the design and construction of new underground projects.

Johannes Gollegger

Studying rock mechanics and tunnelling at the Graz University of Technology opens opportunities to work on interesting and challenging projects all around the world. I started my professional career as a geotechnical engineer at the ILF Innsbruck - tunnelling department. In this time, I already had a good mix between design works in the office and construction sites. The projects were mainly in German speaking countries, as well as some international projects (e.g. USA or Russia). After a very interesting year in Greece at the Metsovo Tunnel, with extremely challenging ground conditions for 3G Graz, I wanted to learn more about TBMs. Therefore, I joined Amberg Engineering Switzerland where I was involved in prominent projects like the Gotthard Basetunnel, or finally the Follo Line project in Norway. Since 2014 I am as self-employed tunnel consultant working in Norway.

Diary of Events

The Long Night of Research at TU Graz
Graz, Austria (2020/10/09)

Researchers all around Austria will allow a unique look behind the scenes and bring their research to life for one night. Our team will show some exciting tests in the rock mechanics laboratory. The first tour will start at 5 p.m. Registration via email addressed to tunnel@tugraz.at.
[additional information]

HSSR-Workshop
Graz, Austria (2020/11/27)

Mini Symposium on Hard Soil / Soft Rock Material and Anisotropic Behaviour. In English. Abstract submission is still possible. Registration will be opened soon. For pre-registration or abstract submission, please send an email to Mr. Manuel Winkler (winkler@tugraz.at).

Barbarafeier
Graz, Austria (2020/11/27)

Annual institute's celebration of the feast day of St. Barbara together with friends from all over the world. After the HSSR-Workshop. Everybody is welcome. We normally start at 7 p.m. Registration via email addressed to tunnel@tugraz.at.

Sequential machine learning for the prediction of rock mass characteristics in the planning and operational phase of a tunnel project
Graz, Austria (2021/01/21)

Lecture by Tom Frode Hansen who is an experienced rock engineer from the Norwegian Geotechnical Institute about modern applications of Machine Learning for rock mass characterization.

2nd ATC2-Symposium 2021
Graz, Austria (2021/12/02)

Symposium by the Austrian platform ATC2 (Austrian Tunnel Competence Center), a collaboration of Graz University of Technology and Montanuniversität Leoben. The aim of the symposium is to transfer innovative ideas and know-how in tunnelling. In German. Abstract submission will be possible at the end of 2020. Registration will be opened in 2021.
http://austrian-tunnel-competence-center.at

Have a look at our Master's Theses

The institute has different research areas and offers numerous topics for a master thesis.

© ÖWF/Voggeneder

- **Mission to the Mars (supervisors: G. Erharter, G. Grömer (OeWF))**

A rather extra-terrestrial research topic looks at the Earth's neighbour Mars. The lava tubes on the red planet are perfect locations for establishing bases for manned missions. In order to use them, the geotechnical instruments must be adapted to the Mars environment, as must the methods for using Earth's stability analysis.

- **Artificial Rock Samples / Anisotropy (supervisor: M. Winkler)**

Rock is a complicated material, for example it is very often anisotropic, i.e. its properties are dependent on certain directions. To learn more about this property and to develop a constitutive model for it, numerical simulations are carried out and artificially anisotropic rock samples are tested in the laboratory.

- **Hard Soil Soft Rock (supervisor: S. Stauder)**
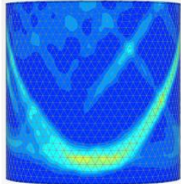
Have you ever wondered what the difference between a stone and soil is? This question is more difficult to answer than expected and is the focus of the research field Hard Soil-Soft Rock (HSSR). The topic of a master thesis in this area is the harmonisation of the nomenclature used in earthworks in connection with hard and soft stone.
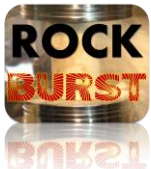
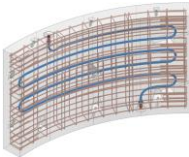- **Rockburst (supervisor: L. Gottsbacher)**

A completely different topic is focusing on a danger on the construction site, rock burst. This hazard is very dangerous because it is sudden and extremely violent. The aim is to study rock burst events on site and to develop test equipment to predict it and reduce its damage to workers and equipment

- **Machine Learning (supervisor: G. Erharter)**
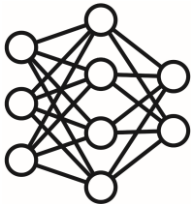
An exciting area of research is being led by the newly founded Machine Learning in Geotechnics (MLGT) Group. The research of this group focuses on machine learning, but the research topics are quite diverse, as one thesis deals with the application of Artificial Neural Networks (ANN) for the prediction of high-resolution landslide monitoring data and another with the analysis and evaluation of geophysical data from Tunnel Seismic Points (TSP).

- **Tunnel-thermal energy (supervisor: T. Geisler)**

You are interested in geology, tunnel construction and alternative forms of energy production? If so, this topic could be interesting for you. The main goal is the extraction of geothermal energy, by using (infrastructure) constructions, with the focus on deep-seated tunnels, so called "tunnel thermal energy". This requires a symbiosis of geology, technical implementation possibilities and tunnel construction.

Moormann, C. (2010). GeoTU6 – a geothermal Research Project for Tunnels. Tunnel. 29. 14-21

In addition to these main research areas, further master theses are supervised, which can be found on the website. These include a numerical approach to classifying rock masses, a study of Building Information Modelling (BIM) in conventional tunnelling with respect to the tunnel face. [overview of master's theses]
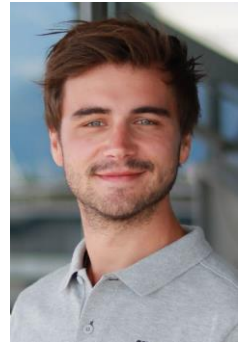
Positions at RMT

Newcomers

Kanthima Intachai

Ms. Intachai is a geotechnical engineer from Thailand. In 2016 she graduated from the Asian Institute of Technology close to Bangkok with a master's degree in Geotechnical and Earth Resources Engineering. The title of her thesis is "Analytical Assessment on Pile Capacity in View of Effects of Groundwater Drawdown and Rebound Associated with Deep Well Pumping". Various scholarships supported her successful university career. From 2016 to 2019 she supervised the Geotechnical Engineering Laboratory & Asian Center for Soil Improvement and Geosynthetics at the same university she graduated from, and she held an executive position at two geotechnical/engineering geological companies in and close to Bangkok, respectively. Ms. Intachai is a member of the Southeast Geotechnical Engineering Society and of the Thai Geosynthetics Society. In 2019 she decided to better herself in geotechnical engineering and applied for a scholarship in Austria to do a PhD abroad. Eventually the scholarship was granted to her, and she is now part of the RMT team. As mentioned already in the last rock report (LINK), a soft rock triaxial testing machine gets installed at RMT at the moment, and within the next three years, Ms. Intachai will elaborate testing routines and sound the technically feasible and the limits of the testing machine, and the working title of the PhD thesis is "Measurement techniques for pore water pressure in hard soil / soft rock material in a special triaxial device". Ms. Intachai, it's great to have you in our team!

Thomas Geisler

Mr. Geisler, aka "Tom", has already settled for some time at RMT, so the term "recent" might not apply to his employment. But as we are more than happy to have him in our team, let us introduce him briefly. Curiously, Mr. Geisler was born in Germany. However, if you ever have the chance to meet him, you will face a funny Tyrolean guy from the beautiful Zillertal who – by the way – also speaks French. He graduated from the Leopold Franzens University in Innsbruck with a Bachelor's degree in Earth Science in 2016, and from Graz University of Technology with a Master's degree in Geosciences in 2019. The title of his Master's thesis is: "Tunnel Boring Machine data analysis with respect to the geotechnical conditions". As the thesis was co-supervised by members of the RMT staff, we were able to get him known very well. His abilities and his motivating spirit has left us no other choice than to ask him to join the team. He is now research and teaching associate at RMT and focuses on two very special topics: extraction of geothermal energy at deep seated tunnels, and accumulation of rock fall debris in high-alpine regions. Tom, we are glad to have you with us!

Open Positions

- A PhD candidate with interest in testing of rocks, and having a knack for operating sensitive testing machines. Send your application for the fully funded part-time position to Prof. Marcher any time.
- A civil engineer with experience in inspection and maintenance of tunnels interested in writing a PhD thesis. Many research questions exist and wait to be answered by you. Funding possibilities depend on your current employment situation. Tell us your interest any time and we will find a funding.

JOIN RMT – we'd love to welcome you.   thomas.marcher@tugraz.at

Cooperation

Cooperations "under construction":

… please contact us in case we forgot you here

... **moving forward**