ROCK REPORT

Mechanics & Tunnelling

Quarterly Newsletter of the Institute of Rock Mechanics and Tunnelling

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October 2020

RMT

NAWI Graz
GEOZENTRUM

TU Graz
Graz University of Technology

MLGT
Machine Learning in Geotechnics

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Marcher's Column

Saint Barbara's celebration at the Institute has a very long tradition and is widely popular. We have waited a long time and hoped that due to the low numbers of COVID-19 infections during the summer, the autumn/early winter would also be quiet. In the meantime it does not look like it will. With a heavy heart we finally had to cancel this celebration for the year 2020.

For me it is now becoming more and more apparent how the very reduced possibilities of direct networking are affecting the colleagues in the tunnel world. The digital contacts are not the same at all. Social events such as the Geomechanics Colloquium in Salzburg are enormously important so that young and old, owners and construction companies, universities, designer and experts can exchange ideas in a relaxed atmosphere and integrated into great exhibitions.

Let us hope that this will be possible again in the course of 2021. We, the Institute for Rock Mechanics and Tunnelling, have in the meantime prepared 2 special things. One is the quarterly RockReport, which should give you an understanding of our recent activities and we are organising a symposium on the research topic "Hard Soil / Soft Rock" with top-class speakers, which we will hold online on November 27th, 2020. We are looking forward to your participation.

Glück Auf and stay healthy!

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Title Picture:
The title image depicts an outcrop of the "Landecker Quartzphyllite" in a weathered state at Stans / Tyrol which is a classical example for HSSR material.

01. October 2020 – published
Georg H. Erharter – editor in chief
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Research Overview

Institute's scientific history - I

Frequently we discuss with students the course of actions required for their projects and theses. Sometimes an important task gets identified and a moment later a member of the institute's scientific staff remembers "wait, that has been investigated already by a former colleague x years ago". So, we recognized that it would be important to summarise the work done since 1992, when the Institute of Rock Mechanics and Tunnelling was founded. Almost 30 years of important research. With the summary below we want to acknowledge the achievements by former institute members, get an idea about the research ourselves to prevent that we do the same research again, to incorporate research results in our current actions, and to inform you our loyal readers.

For the 22nd anniversary of the Institute of Rock Mechanics and Tunnelling in 2014, three former PhD students of Prof. Wulf Schubert, namely Thomas Pilgerstorfer, Nedim Radončić and Bernd Moritz, have summarized the scientific history (until end of 2014) of the institute with a special poster (Figure 1). At the left-hand side one can see the western portal of a tunnel system indicating the beginning of Prof. Schubert's tunnelling career. At the early 1990s he became head of the institute and started three main scientific "tunnel drives"

- Top: the "characterisation" drive,
- Middle: the "tunnel support" exploration drift and
- Bottom: the "measurement data interpretation" tunnel,

which represent the key research topics most of his PhD students have focussed on.

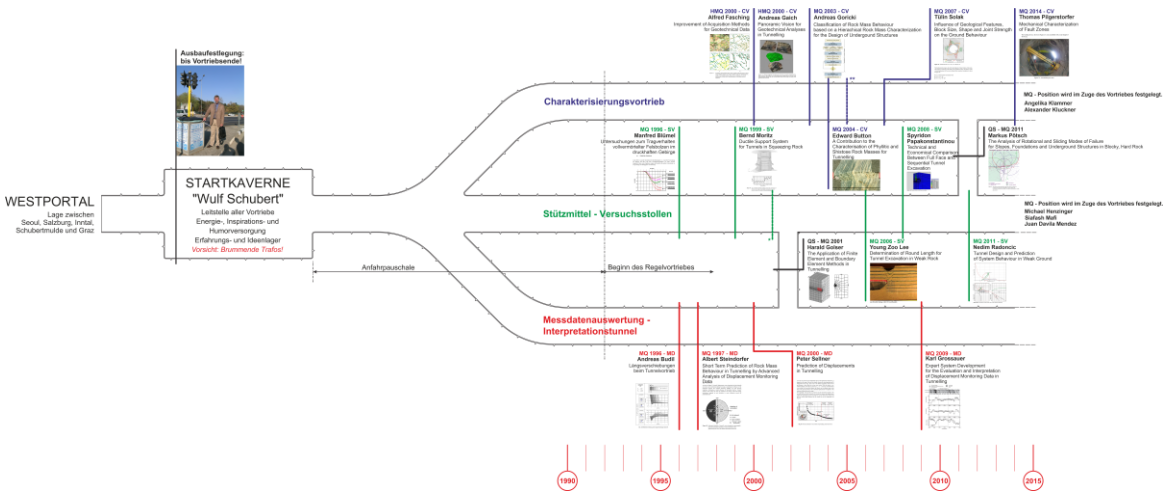

Figure 1: Site plan of the research on tunnel support, characterisation and measurement data interpretation: "Building a tunnel- sir how do you?", by Pilgerstorfer et al. (2014) (in German only). (a high resolution version of the site plan can be found here)

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Research Overview

Institute's scientific history - II

The highlights of the "characterisation" drive started in 2000 with the PhD thesis by Alfred Fasching. He investigated methods for the acquisition of geotechnical data. In the same year, Andreas Gaich published his thesis dealing with the use of panoramic vision for geotechnical analysis. Three years later in 2003, based on the well-known Austrian rock mass characterisation approach, Andreas Goricki published his PhD thesis on the classification of the rock mass behaviour. In the following year Edward A. Button finished his PhD thesis, a contribution to the characterisation of phyllitic and schistose rock masses. In 2007, with her thesis, Tülin Solak contributed to the research of the ground behaviour. She investigated the influence of geological features, of the joint strength, and of the size and shape of blocks in jointed rock masses. Thomas Pilgerstorfer contributed to this tunnel drive with his research on the mechanical characterisation of fault zones, the findings of which he published in 2014. The last process finished at this tunnel drive was by Andreas A. Buyer in 2019. In his research he focussed on the automatic characterisation of joint networks in rock masses. Current construction works are done by Angelika Klammer, who investigates rock properties influencing the probability for rock burst, and by Gerold Lenz, who focussed his research on the characterisation of the ground and system behaviour in water-bearing fault zones. Gerold will defend his PhD in the coming days. Alexander Kluckner works on his thesis about the stress and strain field close to and within fault zones and will publish his findings in 2021.

The basis for the "tunnel support" exploration drift is the investigation on the load-bearing behaviour of fully grouted rock bolts in squeezing rock mass by Manfred Blümel in 1996. Bernd Moritz added to the support of the exploration drift by publishing his PhD thesis about ductile support systems for tunnels in squeezing rock mass in 1999. 7 years later, Young Zoo Lee published his findings on the optimum round length for tunnel drives in weak rock. In the meantime Spyridon Papakonstantinou investigated on the differences between full face and sequential excavation. His PhD thesis was published in 2008. In 2011, Nedim Radončić released his novel approach for the prediction of the system behaviour in weak ground. Eventually, Günther Volkmann finished his investigations on pipe umbrella systems in 2017. And Michael. R. Henzinger defended his PhD in 2019, for which he researched the bedding of segmental linings in hard rock TBM tunnels.

As a key element in Austrian tunnelling is the observation and analysis of the system behaviour during construction, a third scientific "tunnel drive" was necessary: the "measurement data interpretation" tunnel. Andreas Budil performed the first excavation steps. He published his PhD thesis about longitudinal displacements in tunnelling in 1996. Only one year later, Albert F. Steindorfer released his ideas on how to predict main geological features ahead of the tunnel face by analysing displacement data. To predict the system behaviour quantitatively (i.e., displacements) was Peter J. Sellner's task. His approach was published in 2000 and resulted in the development of the software tool GeoFit, frequently used in the Austrian tunnelling business. In 2009, Karl Grossauer submitted his PhD thesis. He reunited all findings on the evaluation and interpretation of displacement monitoring data in an expert system complemented by statistical analyses and recommendations on the definition of the "normal range" of the system behaviour. That the rock mass is not always isotropic has been picked up by Juan Manuel Davila Mendez. He analysed the displacement characteristics of tunnels in layered rock masses and published his findings in 2016.

Last but not least, and —for sure— not less important, research at the institute also has addressed other topics, indicated in Figure 1 by the crosspassages. Already in the late 1990s, Harald Golser applied finite element and boundary element methods to simulate and analyse tunnel drives. His thesis was published in 2001. And in 2011, the masterpiece of Markus Pötsch was released, who analysed the rotational and sliding modes of failure in blocky, hard rock, upgrading the key-block concept of Goodman & Shi.

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Research Overview

Institute's scientific history - III

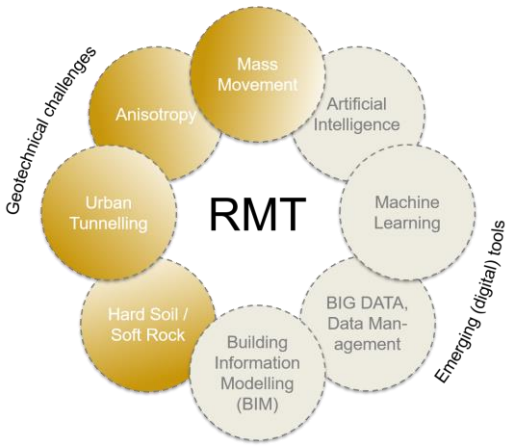

Figure 2: Current fields of research at RMT

Two years ago, Prof. Thomas Marcher became head of the Institute of Rock Mechanics and Tunnelling. Accounting for the current needs in the field of rock mechanics, tunnelling and underground engineering, he chose the topics illustrated in Figure 2 to be the main ones to investigate on within the next years. They can be divided into two sections: at the left-hand side the geotechnical challenges the society and engineers have to cope with and for which research is required; and at the right-hand side (digital) tools which continuously get more important in our fields and which shall help to master our challenges and the increasing amount of information and data available at each project. Some topics Prof. Marcher's PhD students research on are consistent with the three main scientific "tunnel drives" mentioned before. Stefan Stauder investigates the behaviour and characteristics of hard soil-soft rock numerically, in the lab and also in situ. Manuel B. Winkler continues the work on the anisotropic behaviour of layered rock masses and is going to enhance constitutive laws to be able to model such behaviour more accurately. However, there are also fresh ways we follow. Georg H. Erharter applies artificial intelligence (e.g., machine learning) in geotechnics to get more information on the ground (-behaviour) from any measurement or machine data available. Thomas Geisler investigates the potential for the utilisation of thermal energy at long tunnels and Kanthima Intachai investigates the scope of procedures to test hard soil-soft rock with the new triaxial compression test apparatus (see p. 6 in RockReport Vol. 1, No. 2).

But not only the 21 PhD theses should be mentioned when writing about the scientific history of the institute. Supporting the PhD students and performing great research independently, over 100 students have written their Master's thesis at our institute. You can have a look at the full list of scientific publications calling these links: publications in English; publications in German.

In every issue of the RockReport in future we will inform you about the progress of our projects, research findings and important news. So keep following us. And if you have questions, ideas, remarks, we'd love to discuss them with you.

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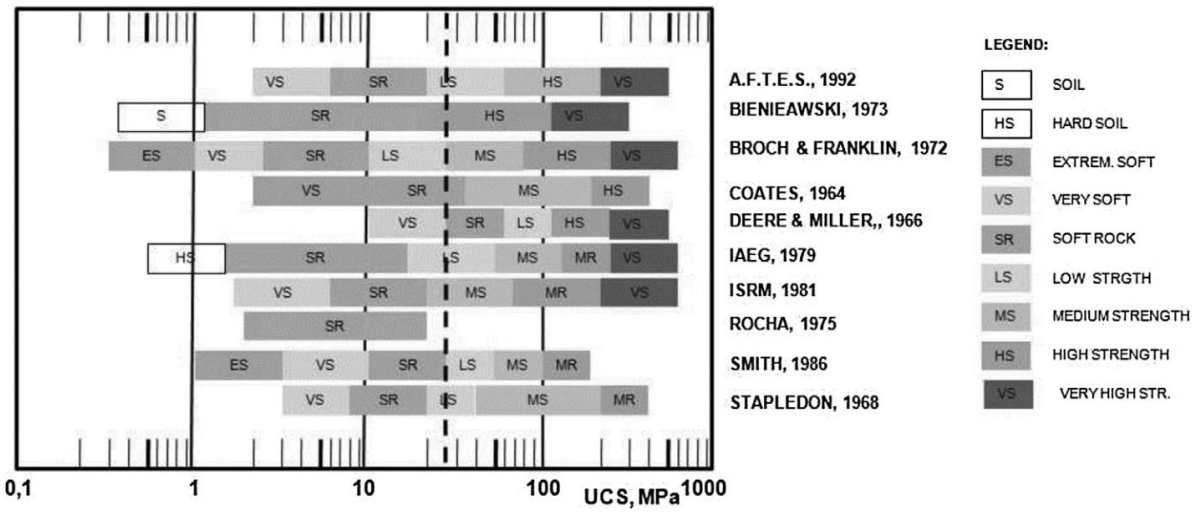
Research Focus Today

Hard Soil Soft Rock

Many engineering problems in geotechnics can be linked to excavations in hard soils or in soft rocks (HSSR). Challenges already arise within the characterization of the material in situ, which is fundamental for all (numerical) calculations.

Therefore, the Institute of Rock Mechanics and Tunnelling emphasizes several fields of research regarding the characterization, sampling, in situ- and laboratory testing of hard soils and weak rocks. Another step towards the improved understanding of this challenging material is the first HSSR Minisymposium which will be held the first time in November 2020 (Webpage).

The first research outcomes were mainly related to numerical analyses and back-calculations of laboratory tests to show and examine the pros and cons of already available constitutive models. Due to the encountered problems of misleading and sometimes incomplete information of literature data, the focus is currently on in situ and laboratory procedures to get and quantify the material parameter of HSSR. So far, the limits of conventional sounding devices like CPT and SDMT were examined at a construction site in southeastern Austria which clearly showed the advantages and disadvantages of “pushed” sounding methods (RR 07/2020). Based on the results, the next step is the utilization of destructive drillings, which are among others in use during TBM exploration beyond the tunnel face, to correlate the recorded drill data and the ground parameter. All these investigations should then contribute towards closing the research gap related to the in situ characterization of hard soils and soft rocks and serve as input for the development of future constitutive models.



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Advances in geotechnical engineering

Workshop Series

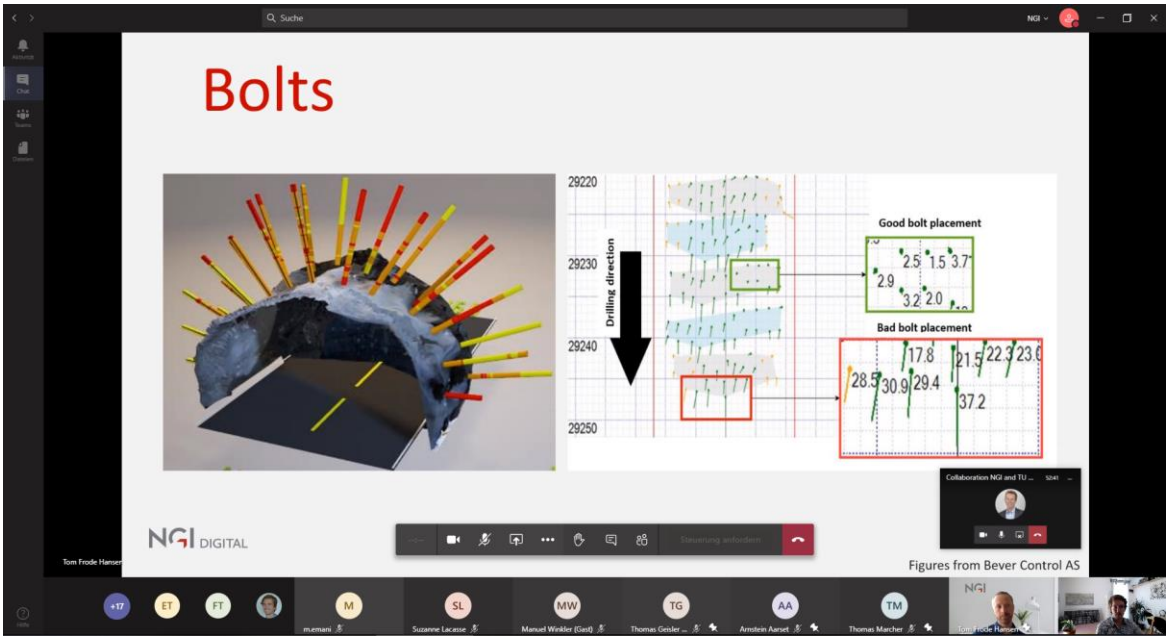
Based on a more than 20-year-old scientific connection to NGI's (Norwegian Geotechnical Institute) Director, Mr. Lars Andresen, Prof. Thomas Marcher initiated a new research collaboration for the institute. The collaboration mainly concerns the topics of Hard Soil Soft Rock and Machine Learning, where the two institutions share common endeavors.

To deepen the relationship, further the exchange of thoughts and include the Institute of Soil Mechanics, there was a plan to hold a joint conference in April 2020 at TU Graz. Of course however, the event fell prey to the travelling restrictions of COVID-19.

Not being discouraged by this, the conference was moved to the cyberspace and transformed into the workshop series "*advances in geotechnical engineering*" featuring four parts between June and October 2020:

- Workshop 1 – CPT
- Workshop 2 – BIM
- Workshop 3 – AI/Machine learning in tunneling
- Workshop 4 – Hard soil – soft rock

So far, the workshop was a great success, benefits both sides and is a marvelous example for working research relationships in times of the pandemic.



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Teaching Highlights

Short course on “How we do our business in Central Europe”

Beginning of this year, Moscow School of Management SKOLKOVO contacted us. They have a client who wants to know about the latest approaches, strategies and technology for shallow and deep tunneling. And they want it to know from us, from the Institute of Rock Mechanics and Tunnelling at TU Graz. What an honor!

End of August, the first short course took place virtually. More than 40 civil engineers, geologists and researchers from Mosproekt Group of Companies, a leading engineering holding in Russia with more than 1500 employees, participated in the course. After a short introduction by Prof. Thomas Marcher, Georg Erharter gave an overview on how to establish a geological model of the project area, advantages and disadvantages of 2D and 3D models, and on investigation measures before and during the construction phase. Then followed a lecture by Alexander Kluckner about the characterization of geomaterials, its general purpose, the idea of key parameters, and matters one has to be aware of when processing test results. Manuel Winkler continued with a lecture on modelling in geotechnics and focused on the difference between ground and system behavior, on scale effects and on analysis methods. At the end, Prof. Thomas Marcher gave a talk on the geomechanical design of tunnels and highlighted possible consequences in case the design is done wrong.

The course was a full success. We got a positive feedback from the participants and additional (online) courses are planned for the upcoming months.

We thank Moscow School of Management SKOLKOVO for the excellent organization of this event.

Site Reports

Development of a methodology for risk management by standardized estimation of the sediment input of mass movements in mountainous areas

Landslides and debris flows pose a threat to settlements and infrastructure and lead - also as a result of climate change - to a far-reaching destabilization of alpine watercourses. Although sediment availability on slopes is a critical factor for the stability of the watercourse network during intensive precipitation, there are neither uniform standards for quantifying the potential availability and quality of sediments nor validated empirical models for estimating sediment inputs as a function of meteorological influences.

The Interreg (ITAT3397-P) Project SedInOut in which the RMT is represented as a scientific collaborator, aims to develop methods for quantifying and characterizing sediment availability, which allow a sustainable management of the sediment for risk reduction. For this purpose, characteristic test areas were defined for which methods for data acquisition and analysis are being developed in order to 1) quantify and characterize the available sediment; 2) estimate the sediment transport from the slopes into the water network; 3) develop guidelines and manuals.

In the province of Carinthia, the debris fans on the eastern flank of the Wasserradkopf were chosen as characteristic test areas (left image).In order to make a validated statement whether it is possible to determine available sediment structures with UAV (drone) based analysis methods, the above mentioned debris fans were flown over and analyzed in cooperation with 3GSM GmbH (right image).

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Publications & Presentations

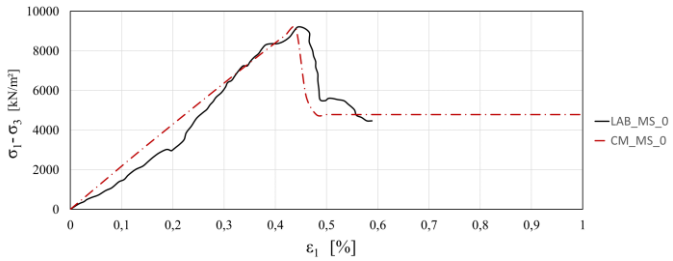
All publications of the institute are listed chronologically on our homepage. Selected papers and presentations are presented here.

Numerical modelling of "hard soil and soft rock" – a contribution towards the understanding of the mechanical behaviour of weak rock

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

The mechanical behaviour of soft rocks can be roughly described by two parts, a pre-peak and a post-peak regime. This material usually shows a stiff response up to a defined yield state under isotropic compression. With increasing stress, the material starts to yield due to the degradation of inter-particle bonds. Post-peak the compression line results from gradual loss of bonding and a further increase of particle crushing. Consequently, porous weak rocks can suddenly collapse whereas overconsolidated soils usually show ductile behaviour.

In a previous work, the authors utilized a constitutive law developed for sprayed concrete and started to calibrate the model parameter. Based on the findings, the current work emphasizes on the application of the Concrete model on a variety of soft rocks under triaxial conditions.



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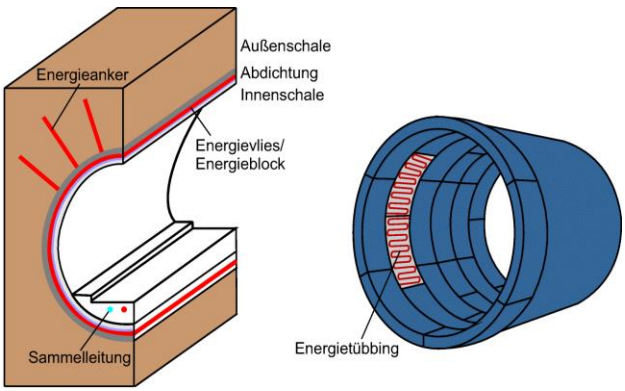
ThermoCluster – a study on potential heat recovery from deep tunnels for the use in smart cities

Geisler, T. (Joint - Tongji - ACTUE - SFB837 Joint Workshop 2020: Recent Advances in Tunneling)

Almost all parts of the world face the same problem: The space above ground is diminishing, which inevitably results in infrastructure construction being moved underground. Furthermore, the demand for climate-neutral energy is increasing and many governments have ambitious climate targets to reach. These circumstances show that there is a need for synergy between these tunnels, which were built anyway, and the geothermal use of them. Various technical options are available for heat extraction, such as energy anchors or energy segments (see below). In addition to an efficient heat extraction, it is just as important to keep the heat to the consumer. In order to evaluate the geothermal potential of deep-lying tunnels, an interdisciplinary know-how in geology, hydrogeology, tunnel construction and process engineering is essential.

Different energy extraction methods for your underground infrastructure.

Source: Kürten S., Koppmann D., Pechnig R. (2018) Thermisch aktivierte Bauteile. In: Bauer M., Freeden W., Jacobi H., Neu T. (eds) Handbuch Oberflächennahe Geothermie. Springer Spektrum, Berlin, Heidelberg



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Faces

Paul Unterlaß

Growing up on a mountain farm at the slopes of the Tauern Window, taking my first steps on alpine meadows (as my parents like to tell) maybe that's what unconsciously sparked my dedication to the broad spectrum of Geology. After finishing my bachelor's degree with a rather pure research project, I started looking for possibilities directed towards the application of geological knowledge for the common good. After having a glimpse into several fields of applied Geology, my decision fell on a specialisation in Engineering Geology. Certainly influenced by experiencing big engineering projects through internship programs. As a newcomer in the field of Data Science and Machine Learning, I got in contact with the MLGT workgroup when I decided to do my master's project focusing on the identification of rock-loads acting on TBM's via operational machine data. My master's project will soon be completed and results will be published – stay tuned.

Manuel Entfellner

Studying geotechnical and hydraulic engineering with focus on rock mechanics and tunnelling at Graz University of Technology builds a solid basis for an ongoing career in the fascinating world of tunnels and tunnelling. Dealing with rock mass as the major construction element and its uncertainties of material properties needs a lot of engineering judgement. In my master's thesis I looked at these facts and the prediction of system behaviour of conventional excavated tunnels in weak ground conditions. After graduation, I started my career three years ago for Implenia Austria GmbH as a site engineer at the Semmering Base Tunnel, Lot 1.1 in Gloggnitz. During many challenging situations on site I was glad to be able to fall back on the in-depth knowledge I had acquired at Graz University of Technology. Since there are so many exciting and open questions in the field of tunnelling, I started writing a dissertation at the Institute of Rock Mechanics and Tunnelling.

Karam Ofeisa

After completing my Civil and Environmental Engineering studies in Damascus, Syria and working as a project supervisor, I started the master's programme Geotechnical and Hydraulic Engineer in TU Graz in 2017. I am currently in the process of finalizing my master thesis in the institute of rock mechanics and tunnelling "Application of Artificial Neural Networks for prediction of high-resolution landslide monitoring data" in which I integrate rock mechanics and tunnelling with Programming, Statistics, Machine Learning and Artificial intelligence. I am already looking forward to bring my knowledge and expertise to solve new challenges in my future career and contribute to helping further integration between Artificial intelligence and tunnel engineering.

Diary of Events

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~~ - Cancelled
Graz, Austria (2020/11/27)

The RMT usually hosts the traditional St. Barbara feast every year. This year, due to the current and very dynamic restrictions regarding the COVID-19 Pandemic, it is unfortunately not possible to hold it in the usual, communal atmosphere. We are looking forward to welcome you again in 2021. Detailed information will follow.

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.

TU Graz
Geotechnical Lectures

The Long Night of Research at TU Graz
Graz, Austria (2021/04/23)

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]

LANGE NACHT der FORSCHUNG
Eintritt frei!

2nd ATC2-Symposium 2021
Leoben, 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

ATC² Austrian Tunnel Competence Center
Graz University of Technology | Montanuniversität Leoben

Have a look at our Master‘s Theses

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

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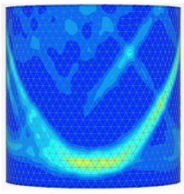
- **Mission to the Mars (supervisors: G. Erharter, G. Grömer (OeWF))**

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.

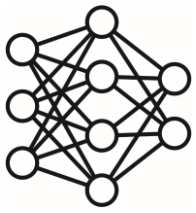
- **Hard Soil Soft Rock (supervisor: S. Stauder)**



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 rock.

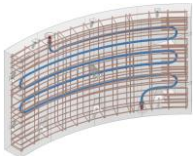
Another proposed thesis should focus on the calibration and testing of the Hoek Brown Softening (HBS) model with respect to hard soils or soft rocks and includes numerical simulations, a case study and a comparison of the HBS to other constitutive laws.

- **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 highresolution landslide monitoring data and another with the analysis and evaluation of geophysical data from Tunnel Seismic Points (TSP).

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



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

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.

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

Mehrdad Imani

I am a Rock Mechanics engineer from Iran. In 2016, I received my master's degree in Rock Mechanics from Tarbiat Modares University (TMU) in Tehran, Iran. The topic of my thesis is "modeling of rock crack propagation at high strain rate". During my graduate study at TMU, I investigated rock failure mechanism, induced-damaged at various strain rate, micro-cracking, and crack propagation using experimental and numerical methods. After graduation, based on my experience and motivation in rock mechanics, I worked at TMU as a research assistant for one year to investigate the effect of brittleness on rock failure mechanism.

In 2018, I started working at the rock mechanics laboratory of Kian Madan Pars (KMP) Consulting Engineers Company. During my work, I was in charge of rock mechanical tests, and also I was responsible for preparation samples, setting up and taking care of equipment, checking data acquisition, evaluation and reporting of the results. It was a great experience because it enabled me to be faced with many challenges during performing experiments, which helped me to expand my horizon and increase my knowledge. These experiences made me more interested to join the institute of Rock Mechanics and Tunneling of TU Graz to work with new advanced machine to do soft rock and hard soil triaxial experiments. After eight years of studying, teaching, researching, and working in different fields to be versatile in the highest level university, academic environment, and company in my country, my insatiable enthusiasm leads me to come here for new experiences and positive contributions. Now, I focus on doing experiment and research in the field of hard soil and soft rock, which play an important role in investigation of shallow tunnel, to achieve the goals of our institute.

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.
- A PhD candidate who is interested in the real-time evaluation of the state and utilization of tunnel linings using wireless sensor technology. This task is part of a national and a transnational project at which several companies, public authorities and universities will cooperate. The project start is planned for spring 2021.

JOIN RMT – we'd love to welcome you.

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Cooperation

… please contact us in case we forgot you here


… moving
forward
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