ROCK REPORT

Mechanics & Tunnelling

Quarterly Newsletter of the Institute of Rock Mechanics and Tunnelling

02 Volume 2
May 2021

RMT

NAWI Graz GEOZENTRUM

TU Graz Graz University of Technology

MLGT Machine Learning in Geotechnics

Content

Marcher's Column

…always keep moving! Not only in Covid-19 times but in general, a continuous development is crucial for our success.

At our institute we have been discussing the creation of a new leaflet. Today we present the central illustration of this leaflet, which is intended to represent the network of research, teaching and laboratory activities at our institute. In doing so, we summarize the initiatives and developments of the last few years.

May 2021: there are bright spots for a somewhat relaxed summer semester. Restrictions will remain with us. But a little travelling (both private and professional) will be possible again and - hopefully - teaching will be possible again in (partial) presence in the coming winter semester.

Last but not least: up to now editor in chief of our Rock Report was Georg Erharter. Georg started the RR-project with big enthusiasm and worked with great energy on continuity of the quarterly newsletter. The effort of organizing and managing to put together all contributions shall not be underestimated. Due to the fact that he is about to complete the doctoral thesis till end of 2021 he asked me to transfer this task to someone else. Fortunately, Manuel Winkler was willing to take this over from the 3rd issue 2021 onwards. Thank you very much, Georg and Manuel!

RMT moves forward, Glück Auf!

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Title Picture:
Slow motion recording of a rock sample bursting in a compressive test. © RMT

04. May 2021 – published
Georg H. Erharter – editor in chief
tunnel@tugraz.at – contact

Research Overview

New leaflet I

We are in the process of setting up a new institute leaflet. In the centre part of this we have created a figure summarizing our focus in 3 circles: “research, teaching and laboratory activities”.

The research focus is on both, urban and deep tunnelling. The potential for the utilisation of thermal energy at long tunnels at great depth (see articles in Baublatt and Think GeoEnergy) is considered as well as the rock burst potential in deep seating underground works (see RR 2020/03 page 4). Research on urban underground engineering is related to “transitional ground conditions” also called Hard Soil – Soft Rock (HSSR). This includes numerical modelling (see RR 2020/03 page 6) as well as in situ and laboratory procedures for such kind of material. Insitu testing started with exploring the limits of conventional CPT devices (see RR 2020/01 page 7 and RR 2020/02 page 9) and has been extended to other kinds of insitu testing methods including the ground parameter determination using rotary drilling (see RR 2021/01).

As outlined by Barton et al. (2014) “*anisotropy is everywhere to see, to measure and to model*”, especially in HSSR. With the research topic of anisotropy our institute has launched its way towards the improvement of current approaches. With putting another focus on experimental works we further want to enhance current laboratory techniques helping us to investigate the mechanical behaviour of anisotropic rocks in more detail (see RR 2021/01 page 3). The “1. Hard Soil Soft Rock Mini Symposium” has been successfully hosted, which focused on identifying possibilities and limits in the research and practice of HSSR including anisotropy (see RR 2021/01 page 4).

With regard to the research field “mass movement” our institute e.g. is part of an Interreg Project (SedInOut – see RR 2020/03 page 9) where we develop methods for quantifying and characterizing sediment availability, which allow a sustainable management of the sediment for risk reduction. Further projects in this field are starting right now (e.g. rock fall hazards, see this issue page 6 and 14).

In the research-circle at the right-handside (digital) tools are illustrated. Those are continuously getting more important in our fields. These tools are helping to master our challenges and the increasing amount of information and data available at each project. One question is about how to create interfaces between 3D geological models, 3D geotechnical codes and numerical codes as well as their compatibility with BIM models (see RR 2020/02 page 10). Today’s scientific studies and modern construction sites are increasingly characterized by large amounts of data. We see this as a chance to gather undetected insights and find never before recognized relationships by systematic data analysis and the deployment of modern Machine Learning algorithms.

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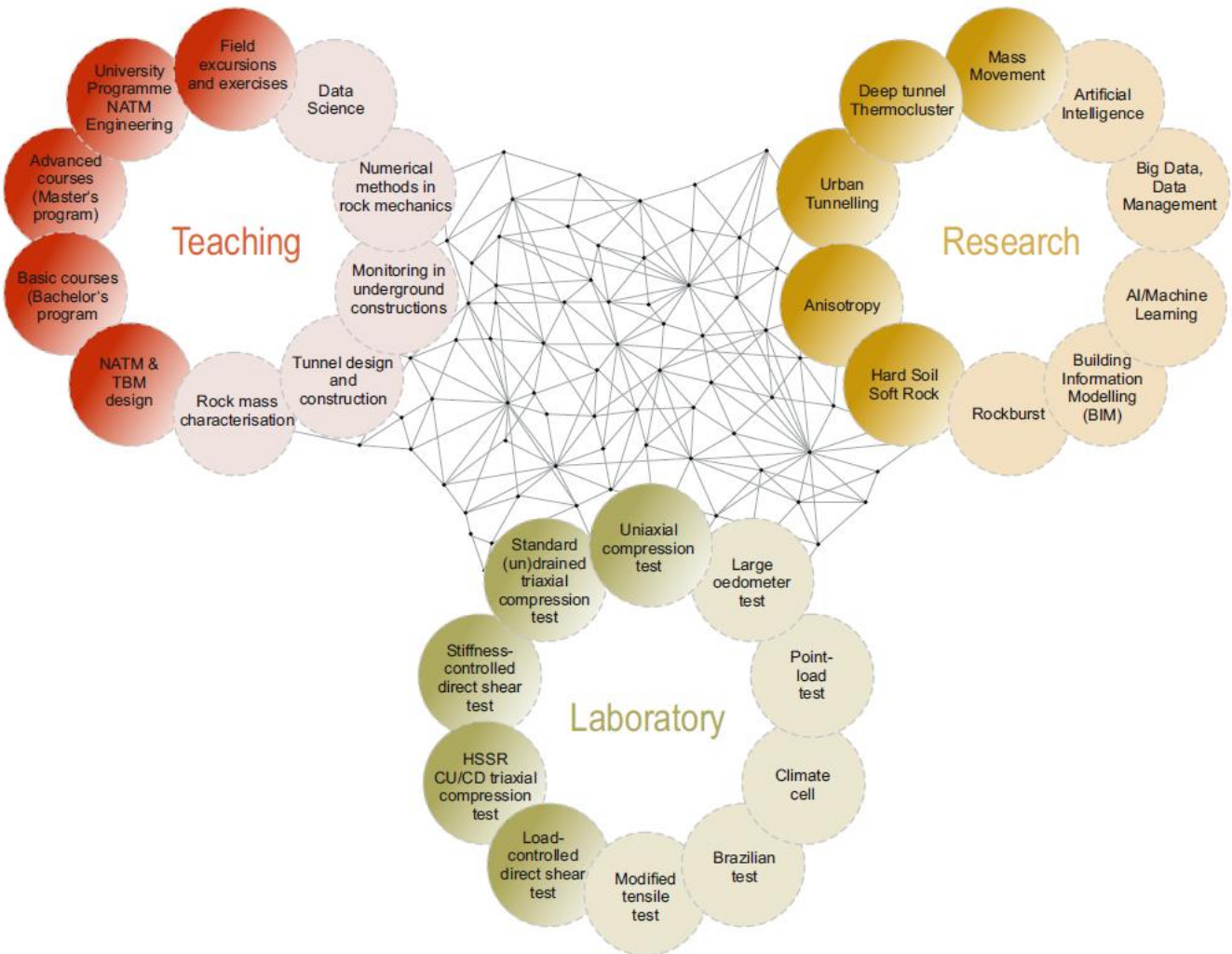
Research Overview

New leaflet II



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Research Overview

New leaflet III

To pursue this goal, we founded the research group “Machine Learning in Geotechnics” - MLGT, which explores applications of Machine Learning to solve problems in the intersection of big data and geotechnics (see also this T&T article). As these problems are not confined to rock mechanics or tunnelling, MLGT was shortly after joined by the Institute of Soil Mechanics, Foundation Engineering and Computational Geotechnics. A series of publications in the field of Geotechnical Engineering have been presented in the past RR-issues. The latest one in the present issue (page 10).

With regard to laboratory we decided in 2018 to acquire a special triaxial testing equipment for HSSR material. 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 (see RR 2020/01 page 6). Since autumn 2020, our institute is operating this new triaxial testing facility. In the upcoming years, we will study the effect of different stress regimes, cyclic loadings, and thermal fluctuations on the material behaviour and the development of the pore water pressure (see Planet Research article for more details).

Teaching has been adapted not only with respect to our new research fields but also regarding the COVID-19 pandemic. New way of teaching have been introduced, such as partial presence mode (see RR 2021/01 page 6). Also, the 6th round of the master’s programme of the international NATM Course started in April 2021 “fully online” in Module 1 with participants from 9 different nations worldwide. Video conferences are taking place between 11:00 hours in the morning till 15:00 hours in the afternoon (CET) to allow participants from Columbia in the West to India in the East to be part of this digital sessions live (see recent RR page 7). One of our special lectures for master students is called “Advanced Rock Mechanics and Tunnelling”. Besides the goal to apply student’s prior knowledge to the design of a “real” tunnelling project a special focus is put on the topics of applied data-science in tunnelling and digital ground modelling (see recent RR page 8). Finally, we are also offering a special course for “Applied Data Science for Geotechnics” which will be held from May 31st till June 2021. Theoretical instructions will be followed by extensive exercises concerning examples of engineering geology, tunnelling, rock mechanics or soil mechanics.

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Recent RMT Guests

R. Kienreich

At the beginning of this year, Mr Rainer KIENREICH from the Office of the Styrian Provincial Government paid us a visit. He is head of the technical department of the district Liezen, a north-western region of Styria. The background for his visit is a very interesting one: in the alpine region of Styria, from time to time, rock fall often triggered by extreme weather events endanger municipal roads and trails. It is simple to declare roads and trails off-limits for public as soon as an exposure to rock fall gets identified. But it is a difficult task for the people in charge to decide upon when to open closed roads and trails for hikers, bikers, etc. Are they allowed to rely on the personal responsibility of each tourist, at least to some extent? Alpine municipals need a guideline on, for example, which procedures they have to follow, which laws to consider, and what the minimum requirements are regarding the on-site survey of the endangered area. For most of those alpine regions, tourism is crucial for their annual income. Having touristic roads and trails closed may affect the numbers of tourists in the long-term. That is something no touristic region wants to have. Together with Mr Kienreich and other experts, our institute is going to address the problem in a research project. We will keep you updated.

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F. Goldschmidt

The Institute of Rock Mechanics and Tunneling is collaborating with the Carinthian Provincial Government on the Interreg project SedInOut. The project aims at characterizing the sediment availability in the alpine area and analyzing it for possible mobilization scenarios. This requires close cooperation and expertise with Mag. Goldschmidt, the provincial geologist of Carinthia, who can provide valuable input. The first parameter surveys were carried out last summer, which is why Mag. Goldschmidt visited the institute after numerous virtual meetings (under strict COVID-19 hygiene regulations) to discuss these results. During the visit, not only the results but also further ideas for exciting research work could be discussed and first steps could be taken. A great cooperation and hopefully many more exciting topics that we can work on together! Thank you very much Mr. Goldschmidt!

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Lab News

Laboratory lectures for NATM course during COVID-19

The laboratory exercise for the NATM course is particularly difficult during the era of COVID-19, since most of the laboratory work consists of practical hands-on activities. It is also very difficult to teach this practical work remotely without the sensation of touching and feeling the rock. That is why the entire team of the RMT-Institute and the laboratory worked together to convey this exercise to the students in the best possible way. In preparation, a camera team shot videos for almost all the work which is needed to prepare the samples for the experiments, which were intended to illustrate the handling of the samples and sample preparation to the students. In addition, videos were also made for the tests to be presented (triaxial, uniaxial, splitting tensile, shear, point-load, p-wave velocity and rebound hammer test).

Normally our multiple failure triaxial and uniaxial post failure test are circumferential strain-controlled mode to monitor the post peak behaviours. We also showed some tests with high-speed load control, to see such sudden brittle failure. These tests were filmed with a high-speed camera.

For other experiments, attempts were made to show them live during the lecture. For example, in our case, the base friction experiments. To convey this live transmission to the students in the best possible way, Mr. Blümel's explanations and the trail of the test were filmed on an elevated platform. Nevertheless, "safety first" as you can see in one of the pictures below, which were taken during the live recording session.

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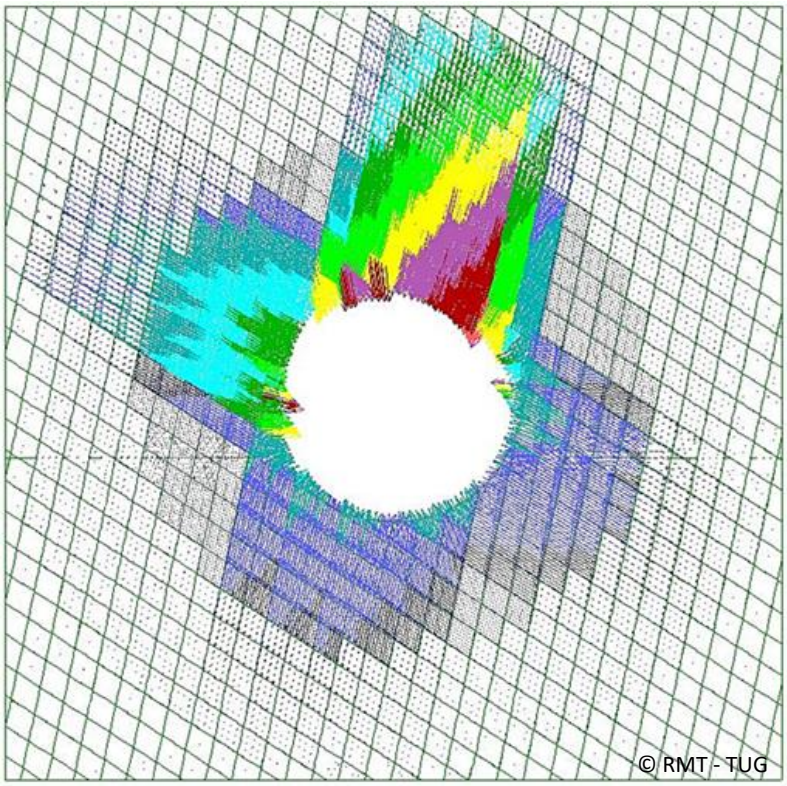
Teaching Highlights

Numerical Methods in Rock Mechanics

Over the past decades, numerical methods have become essential for the design of geotechnical underground structures. In contrast to homogenous soils, for which mainly continuum approaches such as the finite element method get deployed, the behavior of tunnel excavations in jointed rock is very often governed by the discontinuities. To accurately capture the relevant failure mechanisms and structural forces it is therefore inevitably to take these discontinuities into account explicitly, e.g. by the use of distinct element methods.

The lecture ,,Numerical Methods in Rock Mechanics", which is offered each winter semester, aims at teaching our students the essential features and differences of these two numerical methods, the finite element method and the distinct element method. The lecture contains both, theoretical and practical sessions and students are introduced to the numerical software programs PLAXIS (FEM) and UDEC (DEM) which are used for the assignments for solving numerical models of tunnel excavation problems in jointed rock



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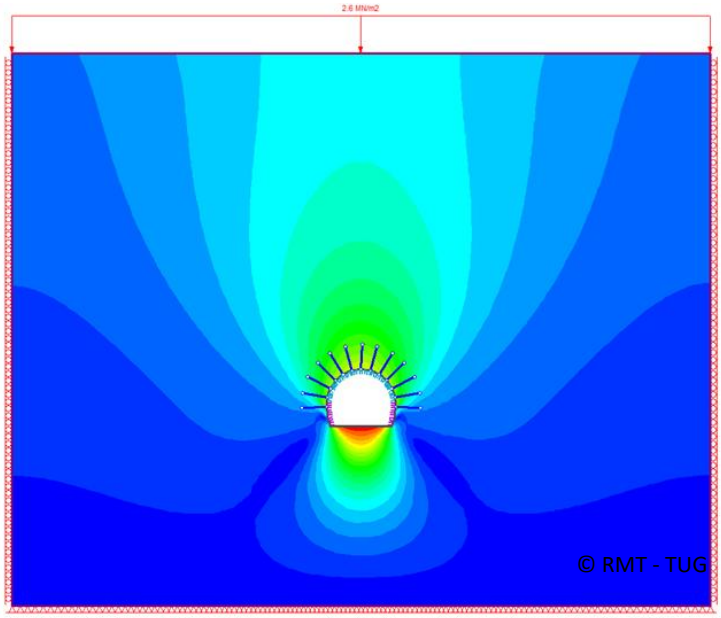
Teaching Highlights

Advanced Rock Mechanics and Tunnelling 1 + 2

With the beginning of this year's summer term our Advanced Rock Mechanics and Tunnelling courses for our master's students started. The main aim of these lectures is the application of the student's prior knowledge to the design of a tunnel structure within assignments based on a real tunnelling project. In addition, these courses include lecture units, held by our institute members and external experts, dedicated to special topics in tunnelling in order to further develop the expertise of our students.

The lecture "Advanced Rock Mechanics and Tunnelling 1" (ARMT1) is devoted to the geomechanical design part for which the students have to subdivide the project area into ground types and come up with reasonable parameters for the respective rock masses. Further tasks within the ARMT1 projects include the evaluation of the ground behavior, the pre-design of the support measures and the assessment of the system behavior. The theoretical lecture units of ARMT1 are concerned with the topics of block theory, the design of tunnel linings, the face stability and surface settlements, rock anisotropy and the characteristics of hard soils / soft rocks.

Within the projects of ARMT2 a more detailed structural design of the tunnel lining is carried out. Information on the acting structural forces is thereby received from finite element calculations. Limit equilibrium approaches are used to compute the required support pressure at the tunnel face. The ground loads on the final lining within both, discontinuity controlled ground behaviors and squeezing rock mass conditions are also determined. A special focus regarding the theoretical sessions is put on the topics of applied datascience in tunnelling and digital ground modelling, besides others such as the design against earthquakes, the design of segmental linings and the mechanized installation of ground support.



Finite element calculation as part of the ARMT2 project

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Publications & Presentations

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

Reinforcement learning based process optimization and strategy development in conventional tunneling

Erharter, G.H.; Hansen, T.F.; Liu, Z.; Marcher, T. (Automation in Construction) Open Access

https://doi.org/10.1016/j.autcon.2021.103701

Reinforcement learning (RL) - a branch of machine learning - refers to the process of an agent learning to achieve a certain goal by interaction with its environment. The process of conventional tunneling shows many similarities, where a geotechnician (agent) tries to achieve a breakthrough (goal) by excavating the rockmass (environment) in an optimum way.

In this paper we present a novel RL based framework for strategy development for conventional tunneling. We developed a virtual environment with the goal of a tunnel breakthrough and with a deep Q-network as the agent's architecture. It can choose from different excavation sequences to reach that goal and learns to do so in an economical and safe way by getting feedback from a specially designed reward system. Result analyses show that the optimal policies have great similarities to current practices of sequential tunneling and the framework has the potential to discover new tunneling strategies.

The Python code to the publication can be found here:

https://github.com/geograz/Tunnel-automation-with-Reinforcement-Learning-TunnRL-

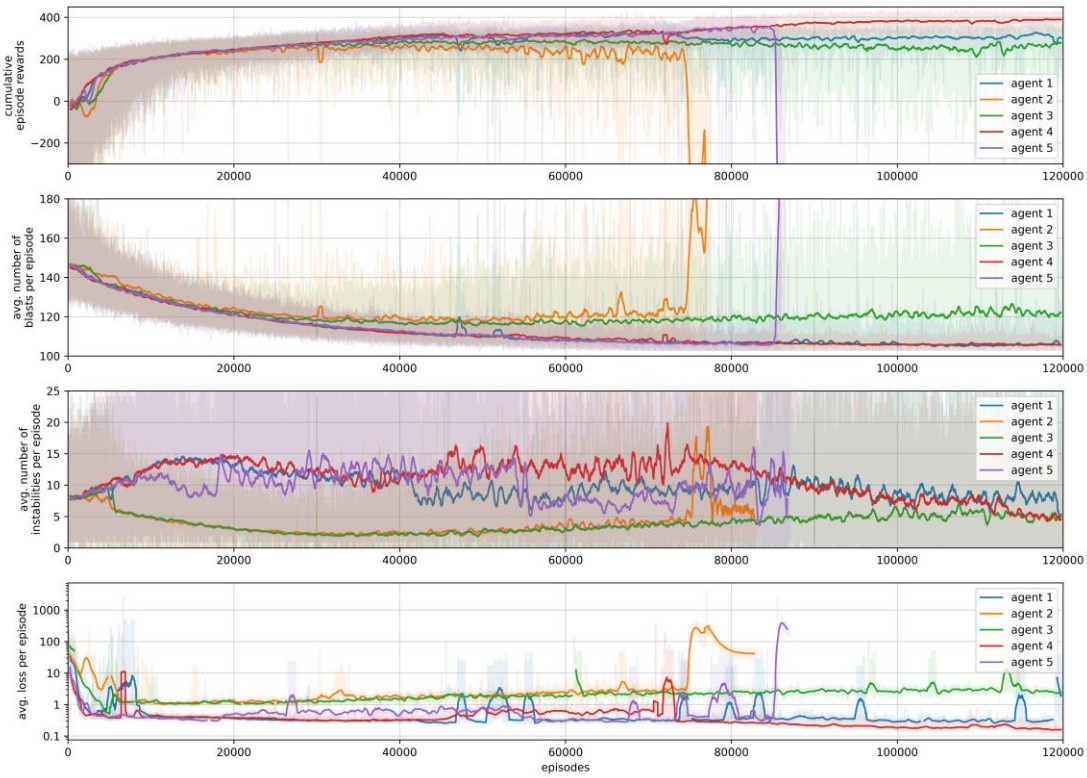

Figure 7 from the paper shows the training progress of different agents that have learned to optimize their performance by minimizing the required blasts per tunnel drive and needed support measures.

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Faces

… today's students and alumni of the Institute of Rock Mechanics and Tunnelling

Nedim Radončić

I studied civil engineering at Graz University of Technology with focus on geotechnics and tunneling. While attending the basic course in Rock Mechanics and Tunneling (held by Prof. Schubert at that time) I thought that I would be my dream to be a researcher at the institute for rock mechanics and tunnelling. The lack of regulations and norms on how to conduct rock mechanics was extremely refreshing after years of learning Eurocodes. Two years later, this dream became true, and I started working on my PhD thesis dealing with the design methodology for ductile support in weak ground. After that, I went to work as geotechnical site engineer at the Koralm Tunnel, eager to learn the practical aspects of tunneling. Four years later, in 2015, I moved to Innsbruck to join the Amberg Engineering team as a project manager, initially responsible for the TBM tunnel design of the Brenner Base Tunnel. Different stations followed: I worked on the design of tunnels below the Suez channel, designed the tunnel supports for the Stockholm subway extension, and lead a detailed design for a part of major hydro power plant project in Chile. Currently I am responsible for the Austrian and Swedish Market segment, with several different and interesting projects to work on. The bottom line is: being a civil engineer specialized in rock mechanics and tunneling allows you to tackle ever-new problems, see great new places and simply to have an interesting profession. Only as a tunnel engineer you can drive a Toyota Hilux through the Andes while listening to rock music, crawl to the cutterhead of a small TBM having problems, define the support measures and then run a numerical analysis in the evening. All of this on the same day. And this -apart from my family and friends – simply makes me happy and always will.

John William de Bradnee Martin

My undergraduate degree in civil and geotechnical engineering was obtained from the University of Queensland, Australia. I am a chartered geotechnical engineer with 6 years' experience, predominantly New Zealand experience. In 2019, I started my master's in geotechnical and hydraulic engineering at TU Graz. Due to COVID-19 I returned to New Zealand to complete the remainder of my master's remotely. The professors and teaching assistants at TU Graz were quick to act with the shift to remote learning, ensuring I was able to continue my studies from afar. I am completing my master's thesis through the Institute of Rock Mechanics and Tunnelling at TU Graz, with my topic focusing on the back-calculation of rock mass parameters at the Semmering Base Tunnel based on the convergence confinement method. In addition to completing my master's thesis, I am presently working part time for Arup NZ (Auckland), with my current work focusing on the temporary rock support for vertical shafts in very weak sedimentary rock. The overlap between my master's thesis topic and work with Arup have been very useful and allowed me to access resources both within and outside of the university.

Florian Thurner

Growing up in a family with a wide background in the construction industry, especially the field of civil engineering has always been truly fascinating. After graduating at a secondary technical school in Graz I pursued a Bachelor in Civil Engineering Sciences and Construction Management at Graz University of Technology which I finished in 2019. Subsequently, I began my Masters in Geotechnical and Hydraulic Engineering which encouraged me in my decision on immersing myself into the field of geotechnical engineering and all its interesting but also very challenging topics. During several internships with a company specialized on ground improvements and deep foundations I had the chance to combine my mostly theoretical knowledge with practical experience. Throughout my internship in 2020 in Norway it occurred that the quality control of dry deep soil mixing improved soil is leading to significant issues due to the high strengths requirements in the recent years. This being an inevitable matter, I decided to focus my Master's thesis on this concern with different solution approaches.

Diary of Events

Hydrogeological (Risk-) Analysis for tunnelling in quartz phyllites regions
Graz, Austria (2021/06/10; 5:15 p.m. CET)

Geotechnical Lectures

Lecture by the senior hydrogeologist at the Brenner Base Tunnel project, Mr Ulrich Burger. He will share his experience and tips on hydrogeological (risk-) analysis for underground constructions and of typical water resources in such rock mass domains. The lecture will be in German.
Registration via email addressed to tunnel@tugraz.at.

35. Christian Veder Kolloquium 2021
Exhibition hall of the city of Graz, Austria (2021/06/24-25)

Annual conference hosted by the Institute of Soil Mechanics with this year's special topic "Inner-City Underground Engineering – Design and Construction". Conference is held in German without simultaneous translation. For further information see:
https://www.tugraz.at/institute/ibg/events/christian-veder-kolloquium/

EURO:TUN 2021
Bochum, Germany (2021/10/27-29)

This year's EURO:TUN focusing on Computational Methods and Information Models in Tunneling will take place in the Conference Centre of the Ruhr University Bochum (RUB). Several Minisymposia will accompany the conference. Prof. Marcher will chair the Minisymposium MS-2 "Data driven models and machine learning in subsurface engineering" together with Ba Trung Cao from RUB and with Zili Li from University College Cork (Ireland). Prof. Marcher is looking forward to meet you there. More information on the conference and the Minisymposia can be found here: http://eurotun2021.rub.de

Barbarafeier
Graz, Austria (2021/11/26)

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

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

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

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. The period for abstract submission ended with March 31st, 2021. The programme will be announced in mid 2021. Registration and further information:
http://austrian-tunnel-competence-center.at
In 2021 the ATC2 Symposium will be held directly after the Tunnel Boring in Difficult Grounds (TBMDiGs) conference, and it will be possible to register for both events at a reduced combination registration price. More information about the TBMDiGs can be found here: https://www.tbmdigs2021.org/en/

The Long Night of Research at TU Graz
Graz, Austria (2022/05/22)

LANGE NACHT der FORSCHUNG Eintritt frei!

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. Registration via email addressed to tunnel@tugraz.at.
[additional information]

Have a look at our Master‘s Theses I

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


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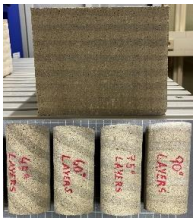
- **Mission to the Mars (supervisors: G. Erharter, G. Grömer (OeWF))**

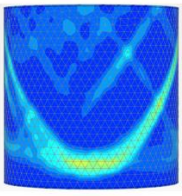
A rather extra-terrestrial research topic looks at the Earth's neighbour Mars. The lava tubes on the red planet are perfect locations for establishing bases for manned missions. In order to use them, the geotechnical instruments must be adapted to the Mars environment, as must the methods for using Earth's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



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

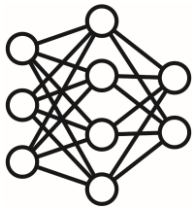
Rock is a complicated material, for example it is very often anisotropic, i.e. its properties are dependent on certain directions. To learn more about this property and to develop a constitutive model for it, numerical simulations are carried out and artificially anisotropic rock samples are tested in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

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



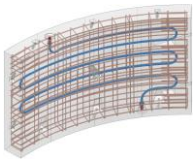
Have you ever wondered what the difference between a stone and soil is? This question is more difficult to answer than expected and is the focus of the research field Hard Soil-Soft Rock (HSSR). Therefore, many engineering problems in geotechnics can be linked to excavations in hard soils or soft rocks. Challenges already arise within the characterization of the material in situ, which is fundamental for all (numerical) calculations. The challenging material behaviour of HSSR leads to a variety of interesting research opportunities and therefore we can offer several Master’s thesis on this topic

- **Machine Learning (supervisor: G. Erharter, P. Unterlass)**



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).

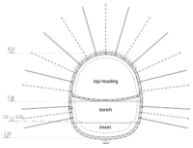
Have a look at our Master‘s Theses II



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

- **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.



Schubert et al. 2014: Geotechnical and construction operational criteria for the selection of full or partial-face excavation

- **Ring closure (supervisor: A. Kluckner)**

In conventional tunnelling driving through weaker zones, it is common to excavate one round of volume in parts: e.g., top-heading, and bench and invert. Reduced displacements result. In very weak zones, partial excavation even might be the only way to cope with ground deformations. Anyway, the moment of ring closure determines the loading of the liner. If ring closure takes place too early, the loading might be too high. If it takes place too late, resulting displacements might be too high. A very interesting topic, especially in combination with the installation of yielding elements. Let’s investigate that.

- **Rock fall hazards (supervisor: A. Kluckner)**

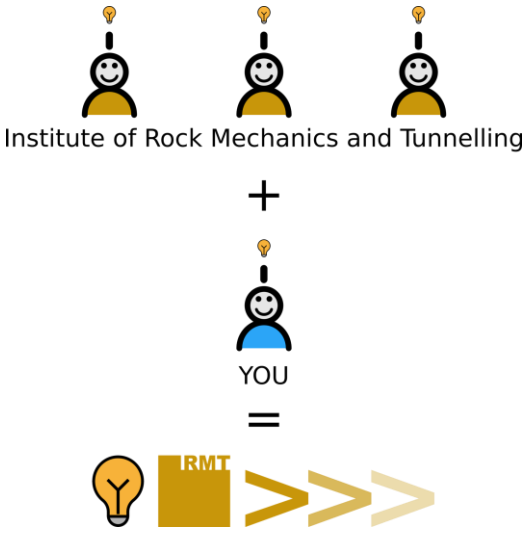
Imagine a hiking trail or a cycle track in alpine regions. Rock slopes may surround the way. And imagine that you walk or drive along this way. Do you watch the rock slopes continuously? A rock block may fall down and endanger you! Or does the municipality the way is located in has to make sure that it is safe for you and others? Is the municipality in charge of for ALL trails and tracks in the mountains, all the time? The risk depends on many factors. The scope of site investigations, the geology, the climate conditions, etc. There is a need for research. Work on this topic with RMT and other cooperation partners.

- **Wireless sensors in liners (supervisor: M. Verient / A. Kluckner)**

Sensors get smaller. Sensors get cheaper. Sensors get more powerful. Is there a way to use many of them in concrete liners of underground constructions to “sense” that a liner approaches a limit state in time before any severe damages occur? This could extent the lifetime of underground constructions significantly. What about wireless energy and data transfer? Let us start now, so we are prepared for the future.

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



Open Positions

- A PhD candidate or Post-doc with interest in testing of rocks, and having a knack for operating sensitive testing machines. Send your application for the fully funded position to Prof. Marcher any time.

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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