# ROCK REPORT

## Mechanics & Tunnelling

IRMT

RMT

# Content

**Marcher's Column**

While compiling the 4th edition of the RockReport, I realised how quickly this year has gone by. You automatically think about why that is and what you have achieved this year. Recapitulating, I leafed through the last RockReports and concluded that a lot has happened!

In addition to numerous scientific theses (MSc and PhD) at our institute, we also had new scientific students and a large output of publications, some of which were combined with an active presence at national and international conferences. The research exchange in Austria and abroad is particularly visible in this issue of the RockReport (e.g. seminars with BOKU Vienna and the University of Innsbruck, as well as collaborations with NTNU Norway and Taisei Corporation, Japan).

This year has enormously strengthened our research focus in the areas of HSSR/anisotropy, data science/ML, rockfall and geothermal energy in relation to rock mechanics and tunnel construction. To ensure this positive development also in the future, in addition to the general available resources, third-party funding must be successfully acquired to allow additional scientific personnel to conduct research on these topics. In this context, I would like to call on clients and the construction industry to continue contributing to university research in the future. For major tunnel projects, the provision of funding would lie in the per mille range of construction costs, however it could substantially contribute to the potential launch of new university research projects. This will also ensure that the latest findings are scientifically exploited on site and made accessible for future generations.

With this issue of the RockReport we have a new editor-in-chief, Paul Unterlass. Thank you for taking on this task and at the same time many thanks to the last editor-in-chief, Tom Geisler!

We thank you for the trustful cooperation and wish you a peaceful and enjoyable Christmas. The very best season greetings. Good health, happiness and success for 2024! We look forward to many new tasks and a good time together.

Glück Auf 2024!

Thomas Marcher

# Research Focus

## Advancements in machine learning for predictive analytics in tunnelling operations

The ongoing collaboration between the Institute of Rock Mechanics and Tunnelling and Taisei Corporation, initiated in 2022, is focused on optimisation of tunnelling drill and blast techniques by using the power of data-driven insights. Central to this collaboration is the employment of machine learning (ML) to analyse measurement while drilling (MWD) data for predictive analytics.

The research in 2023 was on the application of data science methodologies to anticipate the extent of over-excavation, correlating it with a fusion of MWD data and additional technical inputs such as drilling geometry and the volume of explosives per blasting round.

The aim of the project is to identify patterns within the MWD data that could reliably forecast the magnitude of over-excavation. To this end, ML algorithms were employed to facilitate these predictions. A specific innovation was the recommendation of a cascade ML model, comprising two supervised ML algorithms. The preliminary model renders initial estimations, which are subsequently refined by the second model. This cascade

strategy has proven to enhance the prediction of over-excavation by 80% in comparison to the single-model methodology.

The figure illustrates the predicted over-excavation for a singular tunnel face with 20 counter bore holes. The actual over-excavation measurements are depicted in green, the prediction line from a solo model in blue, and the cascade model's forecast in yellow and red.

The model's performance varies when predicting over- and under-excavation, because of values that can be traced back to the imbalance in the training data. Specifically, the dataset contains more recorded events of over-excavation compared to under-excavation. This skewness leads the model to be more proficient at predicting scenarios that are over-represented in the training set.

To mitigate the skewed data in favour of over-excavation, the forthcoming research will explore a variety of techniques to equilibrate the data set, which could potentially refine the precision of the predictions.
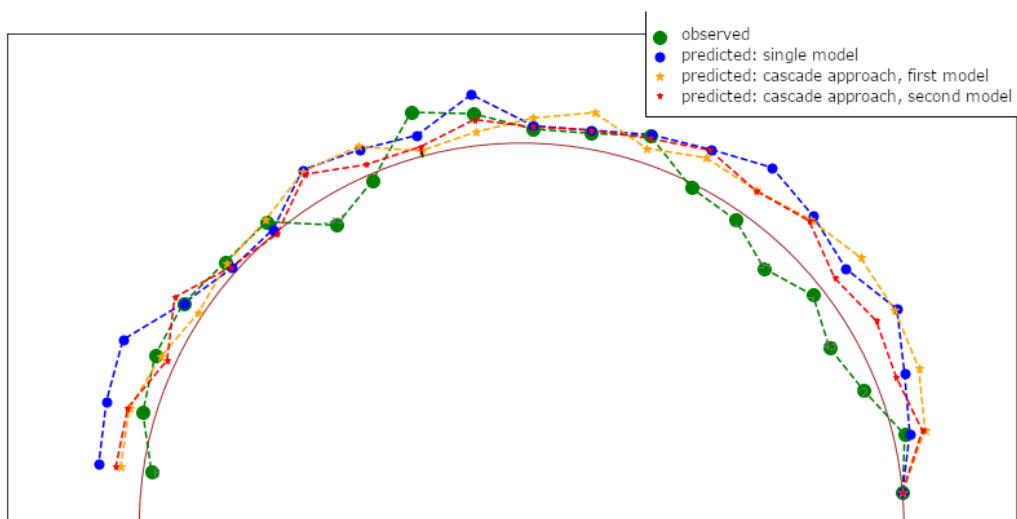


Figure: Over-excavation predicted for a single tunnel face containing 20 counter bore holes. The measured over-excavation are values shown in green, the line of over excavation predicted by a single model is shown in blue, and the cascade model prediction are shown in yellow and red.

# Highlights

## ATC² & Barbara Celebration

On December 1st, 2023, the third Austrian Tunnel Competence Center (ATC²) jointly organized by Thomas Marcher of RMT Graz University of Technology and Robert Galler of Montanuniversität Leoben took place in Graz. This year, the symposium was held under the topics of shallow tunnels and subway construction. In the opening lecture Kurt Fallast talked about the mobility transformation in Graz.

The first session-block, chaired by Thomas Marcher, elaborated on the S-LINK Salzburg project, starting with an overview by Albert Greinmeister, followed by Erich Saurer and Albert Greinmeister on the soil investigations and soil mechanics insights and concluded by Gernot Jedlitschka on the projects challenges and solutions.

The second section themed International projects (part one) chaired by Matthias Flora contained lectures by Robert Thurner on the various geotechnical techniques for the challenging conditions at the WestLink project, Spencer Cavagnet and Luca Mancinelli on a case study from Line 15 South of Grand Paris Express and Alexandre Khatchadourian on the use of fiber-reinforced segments and cement-reduced annular gap mortar on the Grand Paris Express project.

After lunch, section three chaired by Robert Galler contained tunnelling specifics of model-based representation of geological prognosis (un)reliability for shallow tunnels by Ines Massimo-Kaiser and Hannah Salzgeber followed by a lecture on the line crossing U2xU5 construction sections U2/17 to U2/21 – experience gained to date from tunnel excavation works by Helmut Schweiger.

The final fourth section concluded the symposium program with the International projects (part two) chaired by Marlène Villeneuve. Here, Jenny Langford and Stefan Ritter presented their research on assessing potential building damage caused by leakage to urban tunnels and Diego Silva lectured on large highway tunnels under operating metro lines in the soils of Santiago de Chile.

We want to thank all lecturers for their interesting presentations and our sponsors for supporting the event. For those who were not able to make it to the conference, you can find the articles to the presentations in the current edition of Geomechanics and Tunnelling. Hope to see you next year at the guest location in Innsbruck!

Followed by the ATC² symposium our annual Barbara celebration took place in the same premises. Thanks to our sponsors we were able to enjoy a delicious meal and got to celebrate Saint Barbara's day in the presence of colleagues from near and far.

Both events were documented in detail, if you are keen to see the events' photos, do not hesitate and click through the pictures using the cloud links below:

- **ATC²**

- **Barbara Celebration**

# Site Visit

## Angath Site Visit

![ChaMod-HSSR logo: Characterization and Modeling of Hard Soil/Soft Rock considering Anisotropy and Swelling Capacity]

During the months of October and November, the most interesting part of the in-situ objectives of the research project ChaMod-HSSR (Characterization and Modelling of Hard Soil/Soft Rock considering Anisotropy and Swelling Potential) took place at the Angath adit in Tyrol, Austria. One research goal is to extensively monitor the rock mass on site using various in-situ techniques in the exploratory tunnel being excavated at the moment. The argillaceous lithology comprises clayey marls with low thickness sandstone layers and tends to show variable behavior when in contact with water, a typical HSSR feature.

During excavation, various measuring devices, such as a chain inclinometer, various extensometers, measuring anchors, concrete strain gauges and geodetic measuring points were installed and the rock mass was documented using photogrammetric methods. Additionally, an irrigation test field was installed to be able to get a grasp of the in-situ swelling potential of the rock mass. The scope of all these measuring installations as well as the technical specifics meant a lot of know-how, flexibility and long working hours of everyone involved in both, the research as well as the construction projects, so a big thank you for your help to everyone involved at this point!

Currently the measuring devices are all installed and periodically recording any changes in the long-term irrigation test and we are hoping to identify indications of certain trends soon – stay tuned!



Figure: Left master student Andreas Zani documenting the tunnel face for photogrammetric purposes, right Thomas Marcher and Ines Metzler at the construction site.

# Publications & Presentations I

## ISRM 2023 Presentations | Salzburg, Austria

**A guidance for the optimal site location of Cavern Thermal Energy Storage (CTES)**
**(LINK to publication)**

*Session T16: Underground storage for liquid and gaseous media*
*Session Chairs: Robert Galler,* Johann Herdina

Zelzer, S., Geisler, T., Marcher, T.

Abstract:
The production of energy using $CO_2$-neutral methods faces an additional challenge to conserve surplus energy over longer periods of time and to be able to use it when required. One possibility for meeting this challenge is the use of CTES (Cavern Thermal Energy Storage). These CTES store surplus heat in the form of hot water and preserve it for a desired period. Many cities feature the necessary rock formations to build and operate these CTES. For this reason, a guideline has been elaborated that combines the most important geotechnical parameters with the local rock mass conditions. In addition, this guideline pays special attention to the geometric dimensions since these have a significant influence on the stratification of water within the storage medium. It is possible to make a first selection of possible sites and to investigate them in more detail with this geotechnical guidance (Figure).
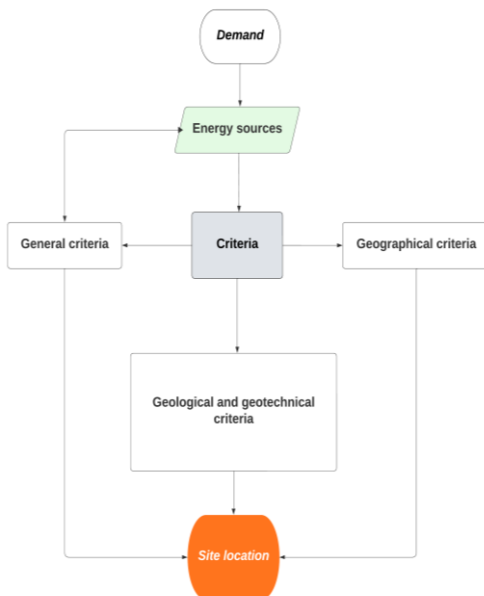
Figures: Left guidance scheme for the selection of possible storage locations. Right master student Stefan Zelzer giving a talk at the ISRM congress.

# Publications & Presentations II

## ISRM 2023 Presentations | Salzburg, Austria

**Comparison of analytical and numerical solutions and displacements around unlined tunnels with arbitrary cross sections inside anisotropic rock masses (LINK to publication)**

*Session T13: Numerical Methods in Rock Engineering*
*Session Chairs: Helmut F. Schweiger, Daniela Boldini*

Winkler, M. B., Marcher, T., Yaz, A.

Abstract

The implementation of closed-form solutions for stress and displacement fields around tunnels with arbitrary geometry, often based on the complex variable theory and the method of conformal mapping, can be quite challenging from a mathematical point of view. In this paper a solution strategy for the implementation of a chosen closed-form solution from literature is presented, including the possibility to account for rock mass anisotropy and arbitrary tunnel geometries. The evaluation of the involved elastic potential functions is described, respectively derivatives thereof, in terms of solving non-linear constrained optimization problems. To validate our approach, the analytical results for stresses and displacements around a tunnel with semicircular geometry are compared to numerical results from finite element computations. The outcome of the study should be regarded as a basis for the development of refined analytical solutions within anisotropic rock masses considering more realistic boundary conditions and effects such as material non-linearity.
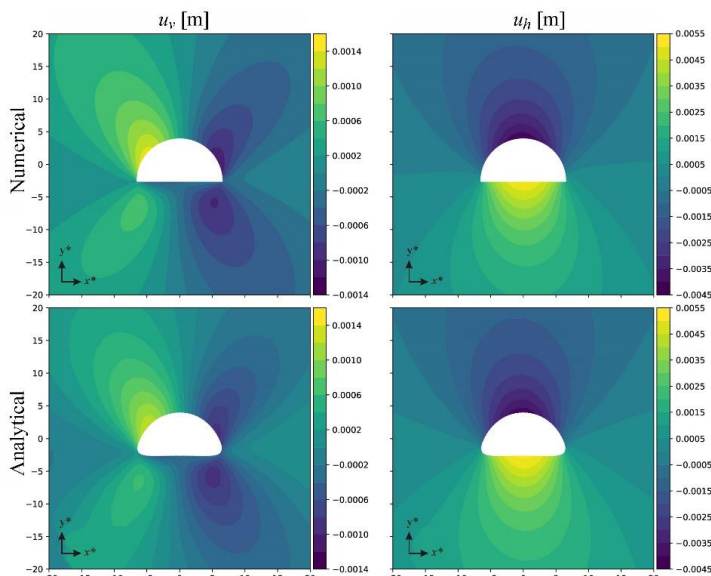
Figure: A figure comparing the analytical and numerical solutions for displacements $u_v$ and $u_h$ alongside the presenter Manuel Winkler in action.

# Publications & Presentations III

## ISRM 2023 Presentations | Salzburg, Austria

**A theoretical framework for calibrating the transversely isotropic elastic rock parameters from UCS tests on cylindrical specimens using circumferential strain measurements**
**(LINK to publication)**

*Session T15: Rock and Rock Mass Properties*
*Session Chairs: Andreas Goricki, Thomas Frühwirt*

Winkler, M. B., Frühwirt, T., Marcher, T.

Abstract:

The standard method for determining the set of five independent elastic constants of transversely isotropic rocks relies on the conduction of at least three UCS tests with directional radial strain measurements on samples with varying isotropy plane orientation. However, in many cases only averaged values for the lateral strains are available from chain extensometer measurements as commonly carried out in rock mechanics laboratories. Such measurement setups disregard the anisotropic deformational behavior of transversely isotropic rock samples which appears as a result of non-horizontal isotropy plane orientations. A direct utilization of averaged radial strains in the determination of the five independent parameters without further considerations is thus not possible. In this paper a possible scheme for the inclusion of circumferential strain measurement information in the determination of the elastic constants of transversely isotropic rocks based on UCS tests carried out on three samples with varying isotropy plane inclinations is presented.
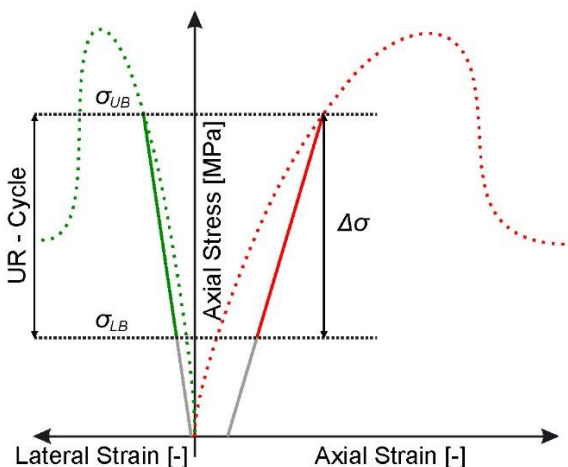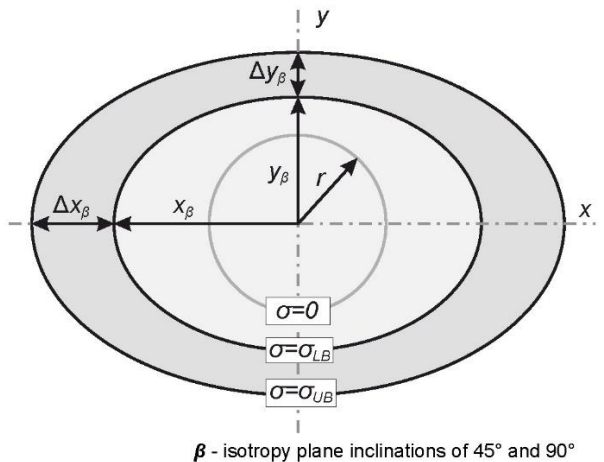
Figure: Considered stress levels along the UR-cycles of the stress-strain curves and associated cross-sectional geometries allowing the definition of theoretical differential circumferential strains as used for a comparison with the measurements.

# Publications & Presentations IV

## ISRM 2023 Presentations | Salzburg, Austria

**MWD data analysis for optimization of tunnel excavation**
**(LINK to publication)**

*Session T05: Digitalisation & Automatisation*
*Session Chairs: Thomas Marcher, Helmut Wannenmacher*

Sapronova, A., Sakai, K., Miyanaga, S., Unterlass, P. J., Soliman, A., Marcher, T.

At ISRM23, Dr. Miyanaga from Taisei Advanced Center of Technology, Infrastructure Technology Research Department, Geotechnical Research Section, and Dr. Sapronova from RMT, TUG, jointly presented the result of their research on "The Drill and Blast Tunnelling Method and Its Optimization Through Data Analysis."

Their presentation was dedicated to the optimisation of the drill and blast tunnelling process by establishing a correlation between the acquired measurement while drilling (MWD) data and the corresponding volume of explosive materials used in each blast.

The researchers provided an overview of various analytical methodologies, including machine learning (ML) techniques. They demonstrated the advances and limitations in use of both unsupervised approaches, such as distance-based clustering, and supervised methods like regression analysis.

A new approach where the correlation analysis used for the data pre-processing procedure, and at the same time used for generating extra inputs for ML models was described. Notably, the models that were incorporating averaged MWD variables per borehole and outputs from the correlation analysis showed the highest accuracy in predicting the volume of explosives (figure).
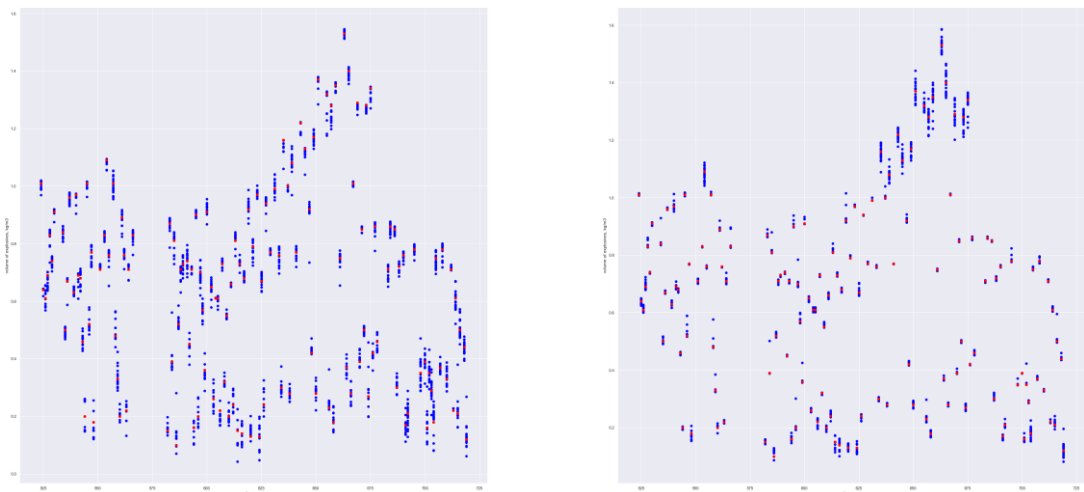


Figure: The outputs from regression model trained on 1) averaged MWD data (left), 2) averaged MWD data and outputs from the correlation analysis (right) are shown in blue. Actual data on volume of explosives are shown in red. The distribution of predicted volume of explosives (blue) for a single face section is attributed to multiple repetition of the "train-test" cycles.

# Publications & Presentations V

## ISRM 2023 Posters & Session Chairs | Salzburg, Austria

Follow this LINK to have a look at RMT's poster contributions to the ISRM Congress 2023.

- **Towards the development of a harmonized inventory database for decision support: automatized information extraction**
  *A. Sapronova, P. J . Unterlass, V. Shringi, T. Marcher*
  (LINK to publication)

- **Rock Fall Risk - Modular Risk Management**
  *R. Kienreich, A. Kluckner, T. Marcher*
  (LINK to publication)

- **A 2023 perspective on Rock Mass Classification Systems**
  *G. H. Erharter, T. F. Hansen, S. Qi, N. Bar, T. Marcher*
  (LINK to publication)

- **An iterative scheme for the determination of the conformal mapping coefficients used in closed form solutions for tunnels with arbitrary geometry**
  *M. B. Winkler, T. Marcher, A. Yaz*
  (LINK to publication)

- **Evaluation of trends in tunnel lining utilization with regards to the moment of ring closure**
  *V. Shringi, M. B. Winkler, A. Kluckner, T. Marcher*
  (LINK to publication)

Our Institute not only contributed with presentations and posters to the ISRM Congress in Salzburg, but also with chairing various sessions throughout the conference, including:

- **Session T05: Digitalization & Automatization**
  Chairpersons: Thomas Marcher, Helmut Wannenmacher

- **Session T15: Rock and rock mass properties**
  Chairpersons: Andreas Goricki, Thomas Frühwirt

## Civil Engineering Design - CEND

CALL FOR PAPERS

Prof. Thomas Marcher and Prof. Wang Xiangyu (Curtin University) currently serve as guest editors for a special issue (SI) of CEND. Civil Engineering Design journal with a focus on "Advancing Infrastructure through Digital Innovation". LINK

The September 2024 issue will be a special issue regarding Data Analytics, Machine Learning (ML) and Artificial Intelligence (AI).

Contribute your latest research and insights to the expanding landscape of Data Analytics, Machine Learning (ML), and Artificial Intelligence (AI). We welcome scholarly submissions showcasing innovative applications, advancements, and practical implementations of these technologies in the infrastructure field. Share your valuable contributions to enrich the discourse and advance the collective understanding of the transformative role played by intelligent data analytics and Machine Learning in diverse domains.

Deadlines will follow soon.

# Teaching I

## Joint Privatissimum – RMT & Institute of Soil Mechanics, Foundation Engineering and Computational Geotechnics

The annual privatissimum held at the enchanting Klugbauer emerged as a beacon of intellectual discourse, as once again PhD students from the institutes of Rock Mechanics and Tunnelling and Soil Mechanics, Foundation Engineering and Computational Geotechnics came together to present the highlights of their research endeavours.

The PhD candidates from both institutes took centre stage throughout the two day symposium, delivering insightful presentations that reflected the depth and breadth of their research. The intimate yet grandiose ambiance of the conference hotel enhanced the sense of community among attendees, creating an ideal environment for robust discussions.

Engaging Q&A sessions followed each presentation, providing a platform for constructive critique and collaborative brainstorming. The event also featured various networking opportunities, allowing participants to deepen existing as well as forging new connections to lay the groundwork for future collaborations.

As the annual privatissimum came to a close, the sounds of scientific dialogue echoed through the halls of the conference hotel. The event not only recognised the individual accomplishments of doctoral students, but also highlighted the collaborative quest for knowledge within the academic community, making it a memorable occasion.

The RMT Team is already looking forward to fascinating technical and scientific discussion at next year's privatissimum.
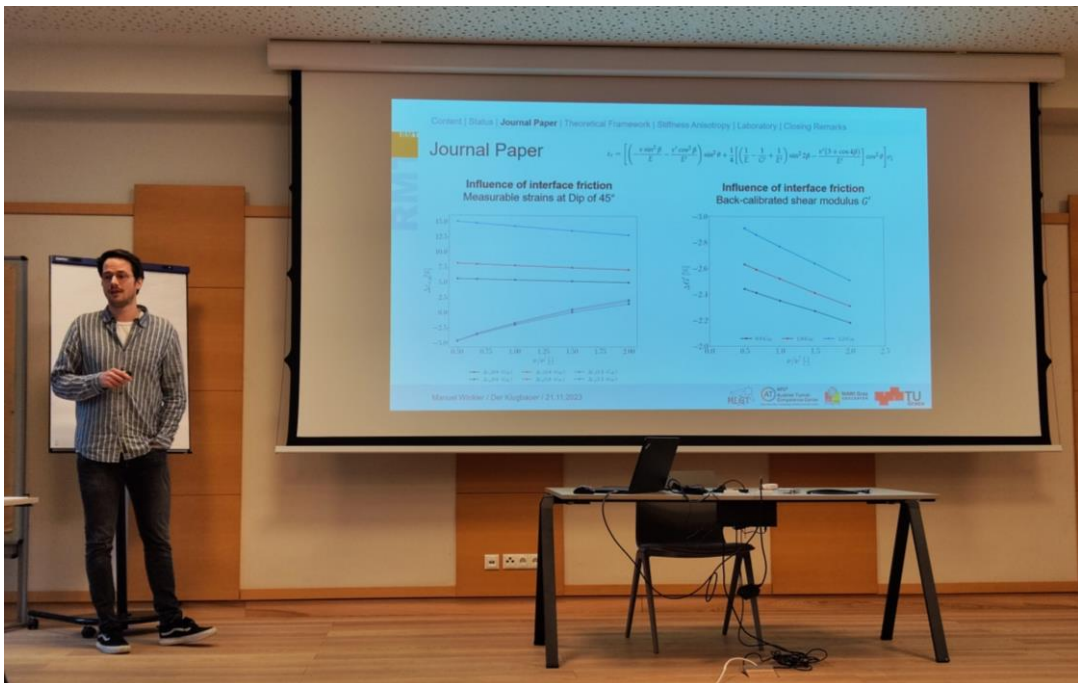


Figure: Mr. Manuel Winkler giving insights into his research on rock anisotropy.

# Teaching II

## PhD Seminar BOKU Vienna / University Innsbruck / Graz University of Technology

On December 11th, 2023, Graz University of Technology hosted the second joint cross-university PhD seminar. Doctoral students from the institutes of Prof. Bergmeister (Head of the Institute of Structural Engineering at BOKU Vienna), Prof. Flora (Head of Arbeitsbereich Baumanagement, Baubetrieb und Tunnelbau University Innsbruck), and Prof. Marcher, convened for an exchange of ideas. The seminar provided a platform for students to present their research, engage in discussions, and benefit from feedback provided by professors and fellow students. This collective exchange of knowledge spanned a multitude of disciplines in the field of civil engineering, reflecting the interdisciplinary nature of academic research within the universities.

The collaborative ambiance not only encouraged the sharing of expertise but also sparked discussions on potential future collaborations and interdisciplinary initiatives. This inclusive environment fostered an open dialogue, enriching the students' work by exposing them to varied perspectives, approaches and opinions.

After the engaging afternoon session, participants transitioned to a convivial dinner setting, allowing for continued discussions in a more relaxed atmosphere. This post-seminar gathering not only provided a space for further networking but also facilitated the formation of connections beyond the academic context.

In bringing together doctoral students and professors from different institutes, the event achieved its goal of promoting a dynamic exchange of ideas. The success of the joint cross-university PhD seminar lay not only in its role as a supportive platform for academic discourse but also in creating opportunities for meaningful networking and social interaction among participants. The promising prospect of future editions ensures the continuity of this collaborative tradition, contributing to the ongoing growth and interconnectedness of the academic community.



Figure: Group photo featuring the participants of the second joint cross-university dissertation seminar.

# Teaching III

## Recent master graduate at RMT – Dominik Lageder

On November 13th, Mr. Dominik Lageder successfully defended his master's thesis, "Geothermal potential analysis of shallow subway tunnels based on tunnel temperature and air flow velocity measurements," at Graz University of Technology under the supervision of Thomas Geisler, Johann Hofinger (iC Consulten), and Thomas Marcher.

Amid the EU's commitment to achieve climate neutrality by 2050, his research delves into the unexplored geothermal potential in Austrian tunnels. Mr. Lageder explores the approach by considering the thermal activation of infrastructure tunnels, which, due to their extensive contact with the ground, could tap into the upper soil layers.

His study examines the influence of tunnel air velocity on extractable heat quantity, using temperature measurements from the Wiener Linien metro network for predictions. By categorizing Vienna metro stations based on temperature profiles, the research identifies the impact of temperature on extractable and injected heat. A three-dimensional finite element model and simulations further estimate the potential, revealing a 30% reduction in absorber performance at low flow velocities.

Moreover, Mr. Lageder's work unveils characteristic temperature profiles in different tunnels, providing insights for predicting the potential of tunnel geothermal systems. High temperature minima and low temperature maxima are indicative of higher cooling and heating capacities, offering a basis for yield predictions in planned tunnels.

Beyond academia, his thesis holds practical significance. It underscores the need for detailed flow analysis in tunnels, improving the reliability of predictions for potential geothermal energy extraction. This work contributes to the optimization of sustainable tunnel construction, fosters synergies in energy use, and paves the way for further exploration in the field.
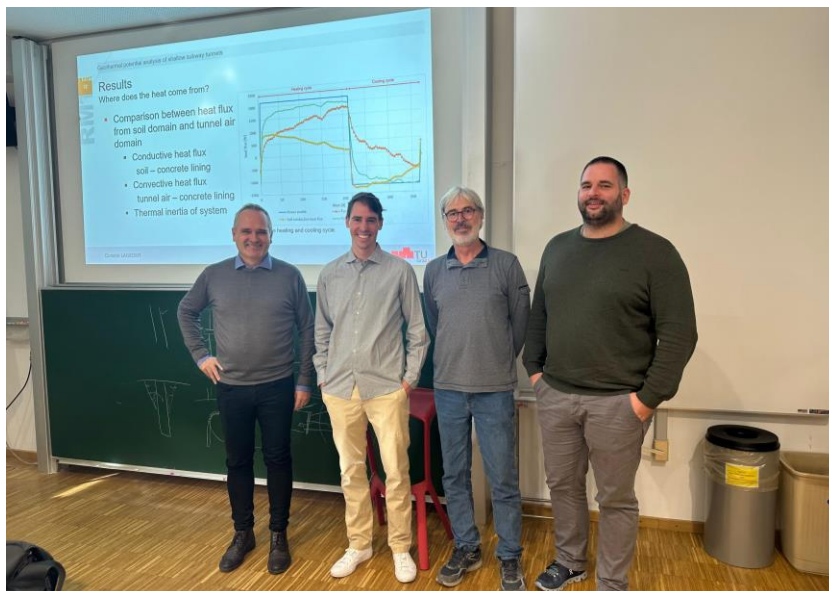


Figure: f.l.t.r. Thomas Marcher, Dominik Lageder, Manfred Blümel, Matthias Rebhan.

# Guests & Visits I

## Deepening the cooperation with NTNU Trondheim

Mid of November we had the opportunity to deepen our cooperation with the Norwegian University of Science and Technology (NTNU) Trondheim and initiate future joint activities.

On 9th and 10th of November 2023 we were proud to host a group of dear colleagues from this well-known Norwegian university and research institute led by Prof. Kristin Holmøy and Prof. Hakan Basarir. Our colleagues are affiliated with the Department of Geoscience and Petroleum of the Faculty of Engineering. Thus, it was not difficult to identify several overlapping fields of activities in our research: Tunnel construction in weak rock mass, hydro-mechanical coupled processes in rocks, geothermal energy production from tunnels – just to mention a few. In addition, and even more interesting for the future, are the possibilities for complementary work on joint projects, because – despite all similarities – the main research focus and technical possibilities at NTNU and TU Graz are different. This is especially the case for the equipment and technical possibilities we have in our laboratories.

At Graz University of Technology we maintain a close cooperation and good relationship between the "geo-institutes" of our faculty, i.e. the Institute for Applied Geosciences, the Institute of Soil Mechanics, Foundation Engineering and Computational Geotechnics and the Institute for Rock Mechanics and Tunnelling. We took the occasion of the visit of our Norwegian colleagues to give them insights in our lab work and our technical possibilities. There was enough time for scientific discussions on details of lab procedures and challenges in lab work done on weak and soft rock material. Great thanks to our colleagues Dr. Latal, Dr. Kaspar and Dr. Rebhan to take the time and introduce their labs to our guests. The feedback of Prof. Holmøy and her team was extraordinary positive!

Our dense program was completed by a brainstorming-round on how to deepen, organise and institutionalise our future cooperation. Exchange of students and academics as well as joint-application for research projects are upcoming activities we are looking forward to in the future.



Figure: f.l.t.r. Thomas Marcher, Thomas Frühwirt, Kristin Holmøy, Manfred Blümel, Eirik Igland Nordland, Jon Runar Drotninghaug, Hakan Basarir.

# Guests & Visits II

## Scientific exchange with Northeastern University Shenyang (China)

After the ISRM Congress in Salzburg in the beginning of October 2023, Prof. Tao Xu from the Northeastern University in Shenyang (China) took the chance of his stay in Austria and visited the Institute of Rock Mechanics and Tunnelling. This visit has been initiated by an already established contact between Prof. Xu and Prof. Marcher. On occasion of his visit in our group Prof. Xu gave a scientific presentation on current research topics his group is working on and he introduced their scientific methods and topics to our team. We identified some similarities in our approaches and also discussed the lessons learned by applying different numerical approaches in our projects. In a tour through our lab we introduced our guest to the experimental work we do and the focus we have in the lab-related research activities. Prof. Xu was quite impressed by the work done at our institute and issued a counter-invitation because he wanted to give the opportunity to his colleagues and students to come in touch with our activities and ideas.

Thus, end of November Thomas Frühwirt accepted the invitation to China and took the chance to visit the Northeastern University in Shenyang. Prof. Xu gave him a warm welcome at the Center for Rock Instability & Seismicity Research of the School of Resources and Civil Engineering. In an academic presentation T. Frühwirt shared current research topics and recent findings with his colleagues. In the subsequent discussion current topics and research activities were introduced by both sides. In a meeting with Prof. Feng, President of the University and past President of the ISRM, T. Frühwirt could learn about up-to-date challenges and topics in rock mechanics in China. A visit of the university`s laboratories related to rock mechanics left a great impression and highlighted potential fields of cooperation. In technical excursions, e.g. to a metro construction site in Shenyang City, more practical aspects and topics related to underground construction have been debated.

Many thanks to Prof. Xu for the overwhelming hospitality! We are looking forward to deepen our contact in the future.
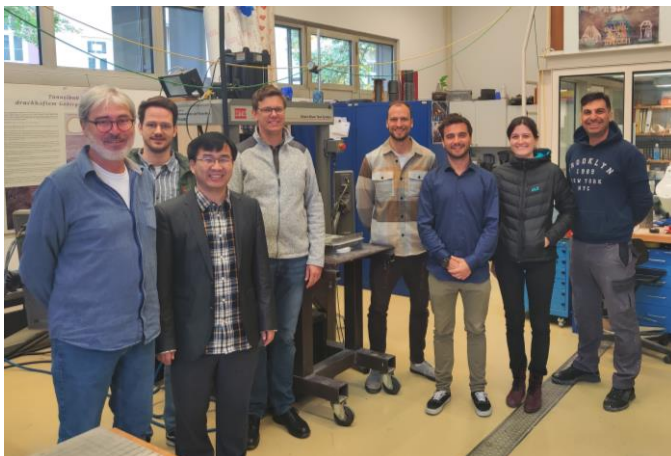


Figure: Visit at the RMT lab, f.l.t.r. Manfred Blümel, Manuel Winkler, Tao Xu, Thomas Frühwirt, Paul Unterlaß, Thomas Geisler, Ines Metzler, Mohammad Bazmi.
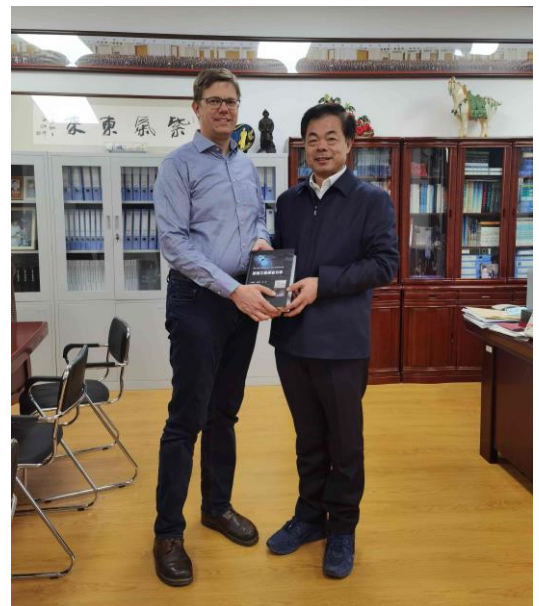


Figure: Prof. Feng handing over his book to Thomas Frühwirt.

# Guests & Visits III

## Thursday lecture series Anne Merete Gilje

As part of the Thursday lecture series of the Faculty of Civil Engineering at Graz University of Technology, the RMT organized a guest lecture by Anne Merete GILJE, Assistant Project Manager of the Norwegian Road Administration. The title was "E39 Rogfast - The longest and deepest undersea road tunnel in the world".

Rogfast will be part of the European Route 39 along the west coast of Norway to improve the road link that will replace all ferry services on this route between Kristiansand and Trondheim. The Rogfast project itself is an underwater road tunnel under construction between the Norwegian municipalities of Randaberg (north of the city of Stavanger) and Bokn in the Norwegian province of Rogaland.

The main part of Rogfast is the approx. 27 km long Boknafjord Tunnel, which is to become the longest road tunnel in the world. It is located up to 400 m below sea level. The project also includes a connection to the island community of Kvitsøy. Completion of the tunnel is planned for 2033.

After an excellent presentation, the floor was opened for a lively question-and-answer session, which gave participants the opportunity to delve deeper into this fascinating project. We want to thank Anne Merete GILJE for the interesting insights into this fascinating project.
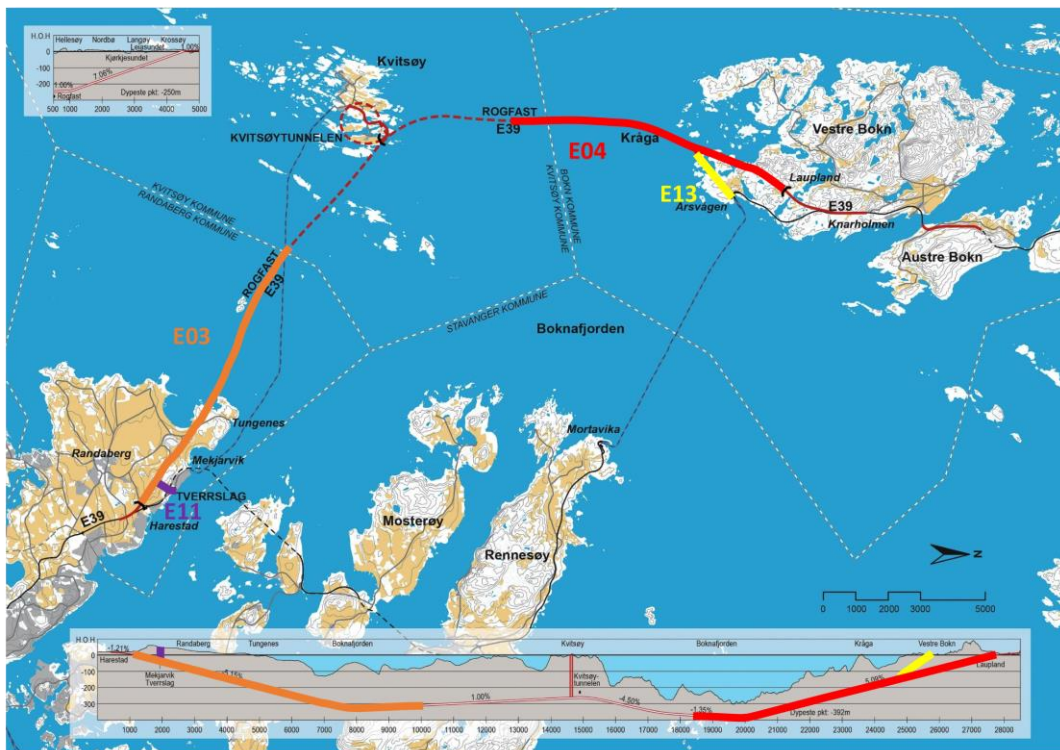


Figure: Overview of the Rogfast road tunnel project, connecting the municipalities of Randaberg and Bokn.

# Faces

...today's with our newest member at the laboratory and a student of our institute.

**Mohammad Bazmi**

It is a great pleasure for me to introduce myself at this issue of the RockReport. My name is Mohammad Bazmi and I was born in Tehran, Iran. My path has taken me from the busy streets of Tehran, through my studies in Business Administration at the University of Tehran, to my current centre of life in Graz.

About seven years ago, the opportunity arose for me to utilise my knowledge and skills in Austria. During a three-year voluntary work, at the retirement home and youth centre in Gleisdorf, I was able to establish valuable interpersonal relationships. After that my professional career took me from a two-year apprenticeship as a mechanical engineering technician at the training centre in Fohnsdorf to positions at Magna Graz and Komptech in Frohnleiten, and finally to RMT.

In my free time, I am active in sports. I played football in a club near Gleisdorf, chess and backgammon are also among my passions.

I am looking forward to working on interesting projects and contributing my knowledge and experience to the RMT team.

Welcome to the team Mohammad!
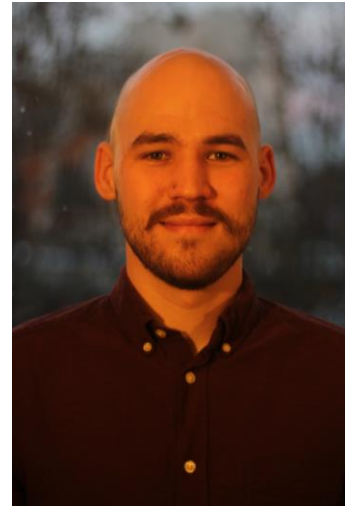


**Mario Wölflingseder**

Towards the end of my Bachelor studies, I was uncertain whether to pursue a master's degree in structural engineering or geotechnics. For that reason, I decided to do my bachelor's thesis at the institute for concrete construction. However, I tried to combine the two fields of expertise and so I was using FEM to do the design a limit state analysis of the inner lining of a highway tunnel intersection block. During this period, my interest in the field of geotechnics grew and I finally decided to attend the master's program "Geotechnical and Hydraulic Engineering".

The course "Data Science in Geotechnics" reignited my interest in the field of programming and exposed me to the fascinating world of machine learning (ML). This led me to starting my master's on unsupervised ML. Using data gathered by TBMs, I am attempting to develop a model to detect rock mass anomalies.

Currently, I am working on my master's thesis, and additionally I am employed as a student assistant at RMT. In the future I would like to dig deeper into the topic of deep learning and possible applications in the field of geotechnics.

# Diary of Events

### > 1st international Rock Mass Classification Conference (RMCC)
Oslo, Norway (2024/10/30&31)

The RMCC will provide an arena for international rock mechanics experts from academia and practice. The conference stands under the paradigm "Rock Mass Classification meets the Challenges of the 21st Century" and will be organized by the Norwegian Geotechnical Institute. RMT's Georg Erharter will be chairman at the conference and Prof. T. Marcher has joined the scientific committee.

Save the date!

Contact: georg.erharter@ngi.no, thomas.marcher@tugraz.at

### > Thursday Lecture Series by Roddy Cunningham
Graz, Austria (2024/03/07, 17:15 CET)
Lecture entitled "Tunnelling the future circular collider at CERN" by Roddy Cunningham, Senior Civil Engineer at CERN in Geneva, Switzerland. The lecture will be in English and will take place in the lecture room HS L (Lessingstraße 25/1, 8010 Graz). Registration via email addressed to tunnel@tugraz.at.
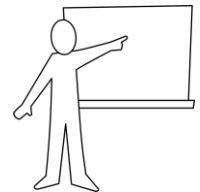
### > Summerschool
Graz, Austria (June 2024)
Third edition of the Summer-/Winterschool cooperation between OST (Ostschweizer Fachhochschulen) and Graz University of Technology. Two days packed with exciting lectures await you, stay tuned for future updates regarding the topic and the exact date.

### > ATC²-Symposium 2024
Innsbruck, Austria (2024/11/14)

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 English. In 2024, ATC² will be hosted at the guest location in the City of Innsbruck. Information on the topics of this event will follow. http://austrian-tunnel-competence-center.at

### > 2nd Mini-Symposium "Rockfall"
Schladming, Austria (2024/11/28)
The second edition of the Rockfall Symposium in Schladming will again shed light on experiences and approaches to this topic from various disciplines. Save the date and stay tuned for further updates.
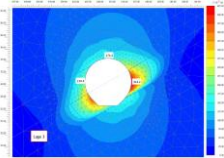
### >"Barbarafeier" 2024
Graz, Austria (2024/11/29)
More information will follow. Save the date.

# Have a look at our Master's Theses I

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

- **A case study: back-calculation of shallow tunnel highly sensitive to surface settlements in urban environment (supervisor: T. Marcher)**

Numerical study. The tunnel has been excavated with side drifts (Ulmenstollen). The focus of the work is on the prediction of the tunnel stability and surface settlements. Numerical analysis shall be performed of which settlements can be expected if a different excavation concept is chosen. The surrounding ground consists of sand. The influence of improving the ground prior to excavation shall be considered as well..

- **Aspects of steel – rock contacts in TBM tunneling (supervisor: G. Erharter)**

New contractual developments set a focus on the effect of shield friction in hardrock TBM tunneling. Low speed and low stress contacts between steel and rock have not been explored a lot so far and the goal of this study is to focus on geometrical and mineralogical aspects of contact points between tunnel boring machine (TBM) shields and the tunnel wall. Research questions that need to be answered are for example: What are the contact points between a TBM shield and the tunnel wall in slanting and curved driving conditions? Which mode of TBM driving is most unfavorable in terms of expected frictional resistance? Are there correlations to standard abrasivity tests such as the Cerchar abrasivity? Methodologically the thesis should contain theoretical work, analog models, and geotechnical laboratory work (abrasivity tests). The master thesis is part of a currently ongoing bigge rresearch endeavor on this matter.

- **Data Science in Geotechnics** (supervisor: **A. Sapronova**)

Advances in engineering equipment that is now capable to delivers massive in-situ data at runtime, open the possibility of employing data analysis and data-driven modeling to ensure proactive risk management and optimize the work. Although a large number of features characterize the geotechnical data, its extreme volumes and sparsity place special constraints on the applications of the data science methods in geoengineering and the special focus shall be placed on the data quality assessment, pre-processing routines, and integration of the data from various sources.

# Have a look at our Master's Theses II

- **Characterization and Modeling of Hard Soil/Soft Rock considering Anisotropy and Swelling Capacity (supervisor: I. Metzler)**

The ChaMod-HSSR project (cf. Rock Report 03/3) aims at an extensive characterization of transitional material excavated with the construction of the Angath adit in Tyrol, Austria. The local Unterangerberg formation comprises hard soil/soft rock (HSSR) with strong anisotropic tendencies as well as a certain swelling capacity due to the clay minerals present within the rock mass. To achieve a comprehensive rock mass characterization, the project objectives are the creation of a reliable and precise database of geological and geotechnical parameters to be achieved via in-situ and laboratory tests, and are to be implemented in numerical models in the third step. The latter aim at predicting relevant, possibly extraordinary material behavior on both, small- and large-scale models. Master's theses may be assigned for selected parts of the project depending on the student's interests as well as the current project and construction progress.

- **Definition of discontinuities in case of foliated rock (foliation) (supervisor: T. Marcher)**

Determination of the mechanical properties of the discontinuities using selected examples of Phyllites in the Central Alps (Switzerland and Austria). Backcalculation on the influence of the schistosity on the tunnel stability. Determining the influence of tunnelling on the activation of potential discontinuities.

- **Rock mass classification systems illustrated in form of a family tree (Master Project)**
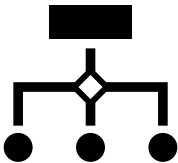
Based on surveys conducted in 2022 and 2023 among the rock engineering community, the dominant rock mass classification systems for underground and slope-related tasks were identified. Using the form of a family tree should help to illustrate the historical development of the different systems and highlight the continued relevance of certain systems.

# Have a look at our Master's Theses III



- **Digital Face (supervisor: A. Sapronova)**
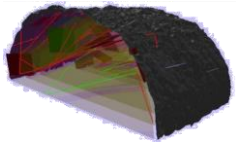
Various data near and at the tunnel face is available during the underground construction: from hand-made technical sketches made by geologists to the 3D point-cloud datasets from seismic surveys. Integration of such information into a harmonized database that will help to forecast the geological conditions and ensure safe tunneling. Ongoing research aims to find methods for the information extraction and integration to move further from the survey data to the dynamically updated visual and digital representation of a tunnel face.
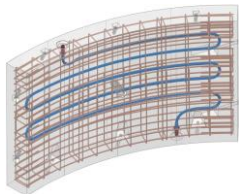


Moormann, C. (2010). GeoTU6 – a geothermal Research Project for Tunnels. Tunnel. 29. 14-21

- **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.
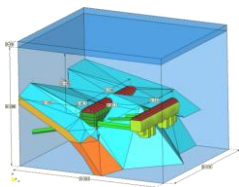


- **A case study: Cavern Stability Analysis (supervisor: T. Marcher)**

In the course of excavating a cavern, difficult tunnelling conditions were encountered in an executed project. The aim of the thesis is to numerically backcalculate the observed behaviour. The involved company offers a position as a trainee and practice-oriented supervision.

# Have a look at our Master's Theses IV

- **Experiences gained with regard to explorations of long, deep-seated tunnels (supervisor: T. Marcher)**

How many exploratory boreholes are necessary in the course of long, deep seated (base-)tunnels? Which insitu and laboratory tests are carried out as standard? How are the explorations distributed between the different project phases? The work focuses on the collection of data based on the experience gained in the construction of deep-seated tunnels in the Alpine region. The data will be systematically analyzed and the results of the different tunnel constructions will be compared.

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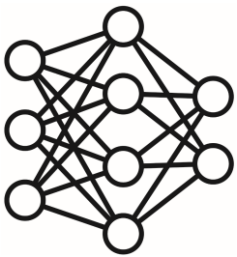
An exciting area of research is being led by the newly founded Machine Learning in Geotechnics (MLGT) Group. The research of this group focuses on machine learning, but the research topics are quite diverse, as one thesis deals with the application of Artificial Neural Networks (ANN) for the prediction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

- **Numerical and experimental investigation of rock anisotropy**

**(supervisors: T. Frühwirt, M. Winkler)**
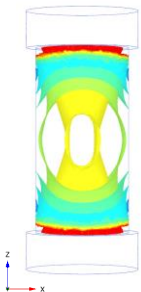
Rock is a complicated material, for example it is very often anisotropic making its' deformational and strength characteristics dependent on the loading direction. To learn more about this phenomenon, numerical and experimental studies need to be carried out.

# Cooperation



… please contact us in case we forgot you here

# ... moving
## forward