ROCK REPORT
Mechanics & Tunnelling

Quarterly Newsletter of the Institute of Rock Mechanics and Tunnelling

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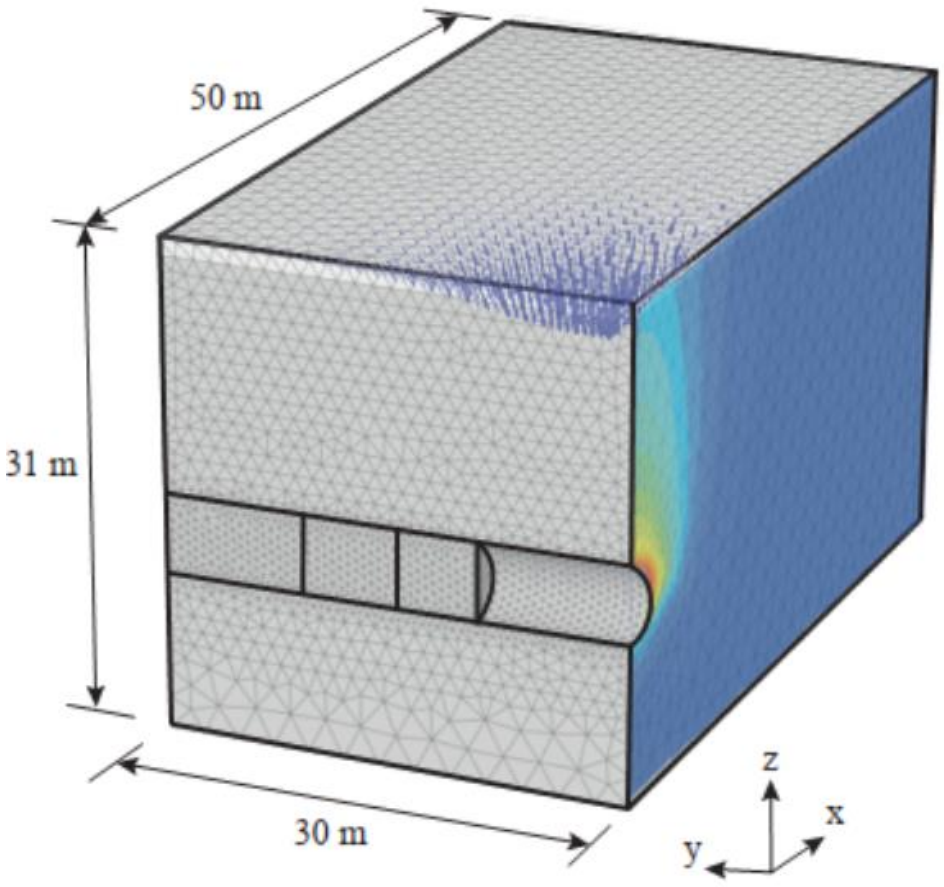
March 2024

RMT



NAWI Graz GEOZENTRUM

TU Graz Graz University of Technology

MLGT Machine Learning in Geotechnics

Content

Marcher's Column

Dear Rock-Report Friends,

Welcome to the start of the 2024 summer semester. Alongside our usual schedule of lectures, we're looking forward to hosting several international guests at our institute. This includes a group from Malaysia, a speaker from Monash University in Australia, and a representative from the innovative projects at CERN. Planning such an eventful semester seemed straightforward until an unexpected turn of events reminded me of the need for flexibility.

Just before the semester began, I took a trip to ski in the Sellaronda area of the Italian Dolomites, anticipating a brief getaway under perfect conditions. Unfortunately, an injury on my first ski run led to a knee operation, sidelining me right at the onset of this busy period and during the arrival of our guests.

Despite my absence, the team at our institute rose impressively to the occasion. Their ability to manage the situation and maintain the smooth running of our programs was outstanding. I owe a huge thank you to every team member for their hard work and adaptability during this time.

We've also seen a notable number of publications in the last quarter, reflecting the broad scope of our research activities. I'm particularly proud of our students who have completed their final theses and of our student employees who have contributed significantly to our institute's achievements.

I hope this issue of the Rock-Report brings you both informative and enjoyable reading, showcasing the strength and achievements of RMT.

Best wishes, Glück Auf!

Thomas Marcher

Title Picture:
Model for the performance study of the hyperelastic cross anisotropic constitutive model. (Cudny et.al., 2024 - *https://doi.org/10.1007/s11440-023-02202-x*)

Picture: Manuel B. Winkler

thomas.marcher@tugraz.at

March, 2024 – published
Paul Unterlaß – editor in chief
tunnel@tugraz.at – contact

Research Focus

UNITEN Workshop

Our institute hosted a group of guests from Malaysia in March. They were eager participants in a comprehensive technical training program on the fascinating field of hydropower tunnel construction. The workshop lasted four days and provided a forum for discussions and knowledge exchanges. The presentation meticulously explored Austria's state-of-the-art tunnelling practices. This provided participants with an in-depth understanding of the latest advances and methodologies in the field.

Our partner institute, the Institute of Hydraulic Engineering and Water Resources Management, played a central role in shaping the event's agenda and creating an environment for intensive training and productive interactions. During the event, Dr. Wolfgang Richter presented valuable information on the dynamic landscape of pumped storage power plants in Austria. The participants gained insight into challenges, innovations, and opportunities in renewable energy infrastructure.

International collaboration is critical to advance our collective understanding and capabilities in tunnel engineering. Diverse perspectives and expertise converged at this event. Thank you very much for that interesting four days!

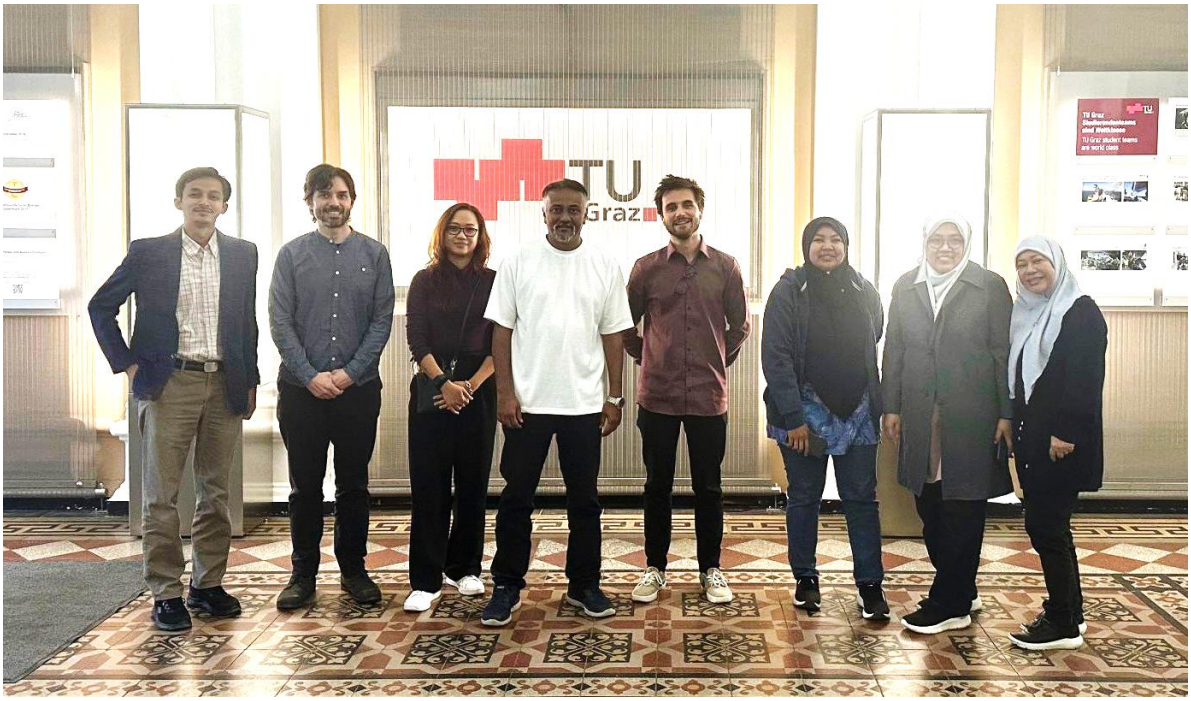


Figure: Our guests from Malaysia with Mr. Wolfgang Richter and Mr. Thomas Geisler.

Highlights

Size dependent behaviour of intact rocks: recent findings and future directions – A/Prof. Hossein Masoumi

Recently Mr. Hossein Masoumi, associate professor in rock mechanics and rock engineering at the department of civil engineering at Monash University (Melbourne, Australia) joined RMT for a four-day research stay.

During his stay, on Tuesday 12th of March Mr. Masoumi held a seminar with the title "size dependent behaviour of intact rocks: recent findings and future directions".

Many students and colleagues from the faculty of civil engineering sciences followed the invitation, filling the lecture room to capacity. Mr. Masoumi's talk was followed by a lively discussion paving the way for future research cooperation's.

Abstract: The design of structures on or within rock masses requires an estimate of the strength of the intact rock blocks within the mass. These blocks of rock can be many orders of magnitude greater in size than laboratory samples typically tested. The properties obtained from these samples must therefore be 'scaled' to equivalent field values. This presentation talks about current methods for scaling strength and other rock properties and, in lieu of noted limitations, presents a constitutive model for intact rock that incorporates size effect. It also includes recent findings and works published regarding size or scale effects in intact rocks under various loading conditions.

Figures: left: title slide of the seminar; right: Mr. Masoumi immersed in the discussion.

Site Visit

Brenner Base Tunnel, Construction Lot H41 – Field Trip

In the course of the lecture “Tunnelling Technology with Tunnel Boring Machines” a group of students had the chance to visit the Brenner Base Tunnel. The students joined by Prof. Thomas Marcher and Paul Unterlaß experienced the TBMs making their way towards Italy at the construction lot “H41 Sillschlucht-Pfons”. We witnessed the TBMs during advance and also had the chance to watch a ring of prefabricated segments being built. Other highlights included the construction of the cross passages and a visit of the on-site segment factory.

Many thanks to Marco Reith, Hans Exenberger and Helmut Wannenmacher from the joint venture ‘H41 Sillschlucht-Pfons Implenia and Webuild/CSC Costruzioni’ for providing us with interesting insights and showing us around at the construction site.

Figure: left: Mr. Hans Exenberger; middle: Prof. Thomas Marcher; and the students of the course Tunnelling Technology with TBM.

Publications & Presentations I

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

“Interlocking strength” in tunnelling – an attempt at classification

Metzler, I., Kluckner, A., Liu, Q., Holzer, R. and Marcher, T. (2024), ”Interlocking strength” in tunnelling – an attempt at classification. Geomechanics and Tunnelling, 17: 17-28.
https://doi.org/10.1002/geot.202300046

The German “Verbandsfestigkeit” (English: interlocking strength) as a description of the tunnel face conditions in conventional tunneling is known as a common, albeit not uniformly defined term, by some also considered to be antiquated or even redundant. The aim of this study is therefore to establish a quantitively substantiated relation between the documented interlocking strength of a geological and geotechnical rock mass parameters as well as parameters related to construction measures to specify the term based on empirical data. Using the statistical method of ordinal logistic regression, it becomes evident that for differing lithostratigraphic units, changing parameters of both, rock mass and construction measures, have a significant relation with the interlocking strength, and must thus be considered a system parameter.

metzler@tugraz.at

The rock mechanical relevance of anisotropy in tunnel design

Marcher, T. (2024), The rock mechanical relevance of anisotropy in tunnel design. Geomechanics and Tunnelling, 17: 29-33. https://doi.org/10.1002/geot.202300052

The assumption of an isotropic material behaviour is still common practice for tunnel design. Strictly speaking, this assumption is only valid if the influence of directional dependencies on the resulting deformations and stresses is marginal. In lithologies that have a high degree of anisotropy, such as shales and phyllites, the orientation characteristics of material properties such as strength and stiffness should be taken into account in order to avoid serious misinterpretations of the bearing capacity and deformation characteristic of the surrounding rock and the tunnel lining. The main focus is to accurately distinguish between the different types and terminology of anisotropy.

thomas.marcher@tugraz.at

Publications & Presentations II

Elastic Behavior of Transversely Isotropic Cylindrical Rock Samples under Uniaxial Compression Considering Ideal and Frictional Boundary Conditions

Winkler, M.B., Frühwirt, T., Marcher, T. Elastic Behavior of Transversely Isotropic Cylindrical Rock Samples under Uniaxial Compression Considering Ideal and Frictional Boundary Conditions. Appl. Sci. 2024, 14, 17. - Open Access

The focus of the work was to investigate the influence of different transversely isotropic parameters and their ratios on the elastic behavior of cylindrical rock samples in uniaxial compression tests. Further, the effect of interface friction between samples and loading platens on the resulting strain distributions was analyzed within numerical models. No significant influence of frictional boundary conditions on the back-calibrated values of the elastic parameters could be identified, suggesting that friction-reducing measures in uniaxial compression tests on transversely isotropic samples with predominantly linear behavior are not required.

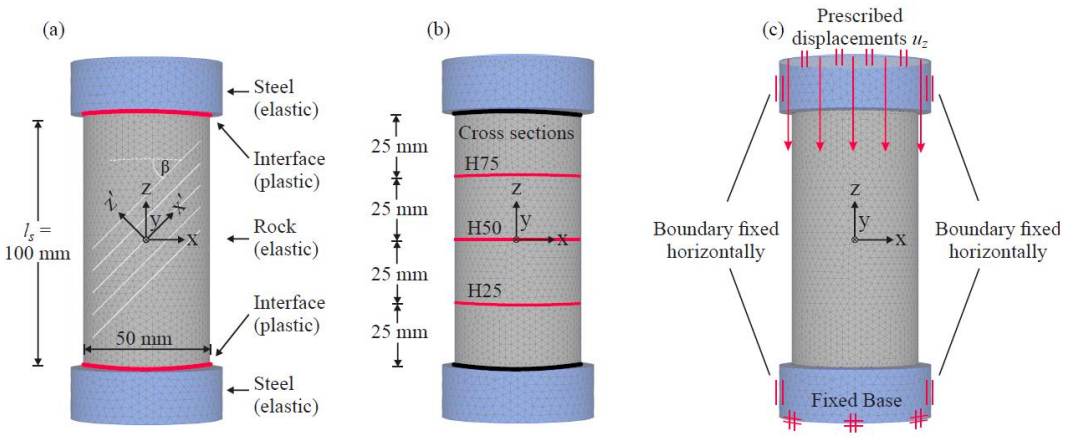


Figure - Illustration of the numerical model set-up (taken from Winkler et al. (2024) CC BY 4.0).

Modelling tunnelling-induced deformation in stiff soils with a hyperelastic–plastic anisotropic model

Cudny, M., Lisewska, K., Winkler, M. et al. Modelling tunnelling-induced deformation in stiff soils with a hyperelastic–plastic anisotropic model. Acta Geotech. (2024).
https://doi.org/10.1007/s11440-023-02202-x

In this paper, the tunnelling-induced deformation in anisotropic stiff soils is analysed using FE modelling. A new hyperelastic–plastic model is proposed to describe the anisotropic mechanical behaviour of stiff highly overconsolidated soil. Formulation of the novel model is presented. Tunnelling-induced deformations are investigated based on 2D and 3D simulations of a simple boundary value problem. Finally, the tunnelling case study at St James Park is back analysed using the proposed material model in plane strain conditions.

Publications & Presentations III

Enhancing the performance of open geothermal tunnelwater systems by heat absorbers

Geisler, T., Richter, W., Marcher, T. Enhancing the performance of open geothermal tunnelwater systems by heat absorbers. Tunnelling and Underground Space Technology, Volume 145, 2024. - Open Access

The symbiotic use of underground infrastructure among the improvement of transport routes and the generation of geothermal power, is increasingly gaining momentum. Geothermal systems can be divided into open and closed systems, which differ from each other by the circumstance that closed systems have a closed circuit and open systems do not. For the application of geothermally closed tunnel systems, elegant solutions have been developed, while geothermally open tunnel systems are still dictated by the characteristics of the water entering the tunnel. In order to address this issue, concepts for tunnels under design as well as existing tunnels, were developed. The concepts allow the temperature of the inflowing water to be risen, and thereby increasing the geothermal power. The presented approach is based on the channeling of cold tunnel water inflows through absorber sections in areas of high overburden to supply them with additional energy before diverting them back into the drainage system. In order to obtain indications on the effectiveness as well as on the sensitivity of the components and influencing parameters, numerical models were created and subsequently compared, since no empirical data are available. The results show that it is possible to enhance the geothermal performance, but with decreasing efficiency over time.

geisler@tugraz.at

Rock Mass Structure Characterization Considering Finite and Folded Discontinuities: A Parametric Study

Erharter, G.H. Rock Mass Structure Characterization Considering Finite and Folded Discontinuities: A Parametric Study. Rock Mech Rock Eng (2024). – Open Access

The quantification of a rock mass's internal structure and description of discontinuity properties is imperative for modern rock mass characterization. This study builds on decades of rock engineering development by reviewing and revising different parameters such as the rock quality designation (RQD), volumetric joint count (Jv), the Pij system and others. Analyses of these parameters are done by means of a Monte Carlo simulation that generated 5000 samples of discrete discontinuity networks including finite, folded and very low to very high discontinuity densities (Jv range: 0.5–117 discontinuities/m 3), thus representing a wide range of possible geological scenarios. P10, P20, P21, P30, P32, RQD and the fractal dimension of the rock mass are virtually measured on these samples and a range of higher level parameters that are used in practical rock engineering computed and their relationships investigated. It is concluded that parameters which are based on subjective estimations of discontinuity spacing, the number of discontinuity sets or RQD are not suited to describe the rock mass structure in cases of demanding geological scenarios featuring many discontinuities, weak and anisotropic rock masses, metamorphic rock masses, folded rock masses, etc. By revising classical parameters and their relationships, this study contributes to basic rock mass characterization and furthermore paves the way for future developments by making the developed discrete discontinuity network dataset and all included codes openly accessible to the rock mechanics community.

erharter@tugraz.at

Upcoming special session / issues

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. LINK

Save the date!

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

Civil Engineering Design - CEND

civil engineering design

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

Recent master graduates at RMT

Ken Visnar

In January 2024, Mr. Ken Visnar successfully defended his master's theis titled "Data Analysis of TBM Data at the GKI Site". This study examines the utilization of state-of-the-art Tunnel Boring Machine (TBM) operational data pre-processing and analysis techniques in the context of a case study involving the 23 km long headrace tunnel built by the Joint Power Plant Inn collaboration (GKI) in schist rocks using a double-shield TBM. It is particularly relevant in light of recent developments in the ÖNORM B 2203-2 standard revision, which investigates the use of TBM data for machine-assisted rock mass classification. The study involves the use of Python programming language and its modules, as well as statistical methods, to process and evaluate a large quantity of TBM and geological data collected during the construction of the tunnel. Additionally, it focuses on interpreting the data from thrust-penetration and shield friction curves as an important step for appropriate rock mass classification . The results indicate that the geological data is relatively homogenous and that shield friction could not be determined due to missing sensor data. The study highlights the crucial role of meticulous pre-processing and acquiring sufficient data.

unterlass@tugraz.at

Thomas Bostjancic

At the same time, Mr. Thomas Bostjancic also successfully defended his master's thesis titled "Correlating lab data in argillaceous soft rocks: towards a comprehensive database" and thus concluded his master's studies in Geosciences, a joint NAWI Graz study program of both, the University of Graz and Graz University of Technology. His scientific work was conducted under the supervision of Thomas Marcher and Ines Metzler.

His research aimed at providing a statistically based starting point and basis for characterizing a hard soil/soft rock lithology, extensively monitored in the ChaMod-HSSR research project. In preliminary investigations, a considerable amount of data had already been collected from laboratory tests, which were further compared with other similar lithologies and their test results to see whether trends or correlations could be identified for rock and rock mass parameters. The data basis gives us a good overview for the research project of what we can expect with regard to laboratory test results.

RMT wishes the graduates all the best for their future endeavours!

metzler@tugraz.at

Teaching II

Lecture Alert: Applied Data Science for Geotechnics

Data science is an emerging interdisciplinary field that aims to extract insights from various datasets using mathematical methods and programming algorithms. With the present advances in engineering equipment capable of delivering massive in-situ data at runtime, a possibility for data-driven analytics is opening for the geotechnical disciplines. The application of data science branches, like statistical analysis, machine learning, big data mining, allows to correlate seismic attributes with geological properties, helps to remove the subjectivity in the evaluation of the geological conditions, and plays a major role in building effective proactive risk management and process optimization routines.

The modern tools and methods of data science applicable to geotechnical engineering are presented in the “Applied Data Analysis for Geotechnics” course, offered in the summer semester. The course aims at teaching our students the essentials of data analysis using the Python programming language and covers an extended introduction into the data science analytical concepts.

There are still a few places available, you’d better be quick!

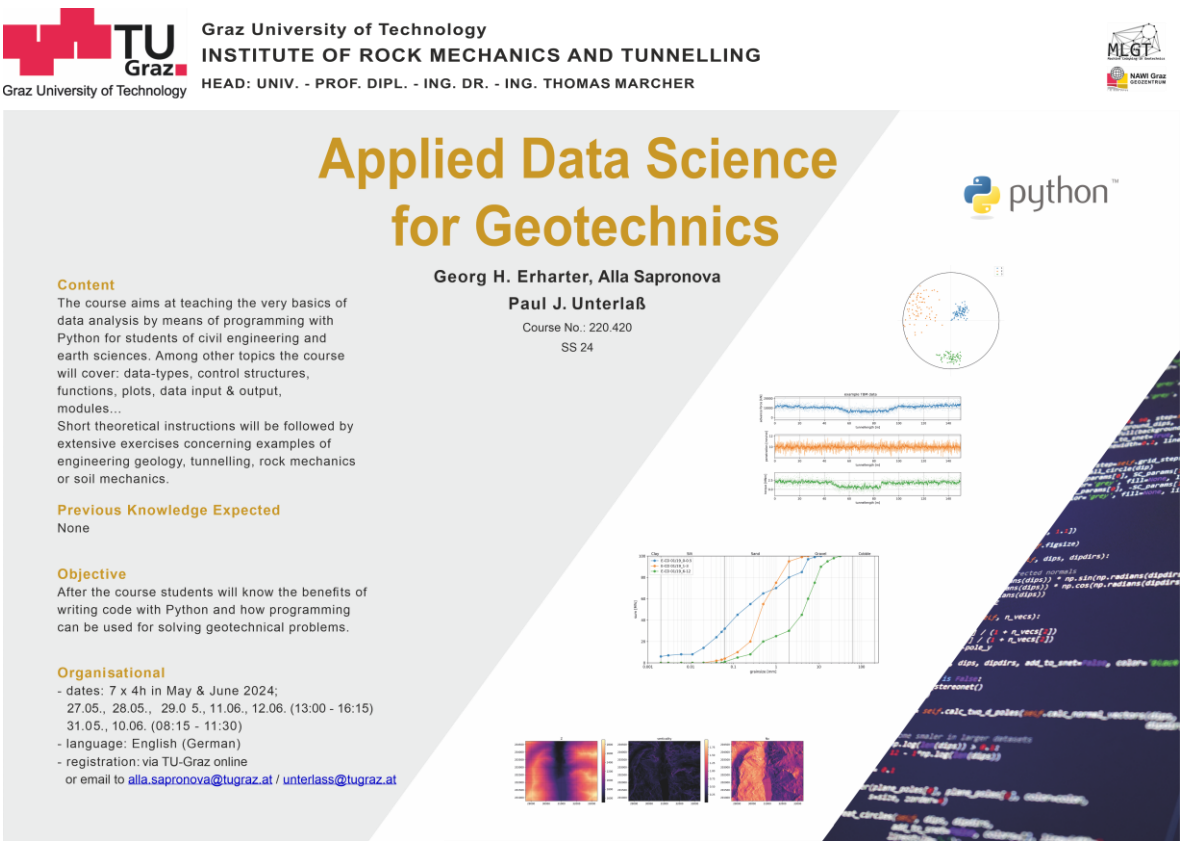


Figure: Poster advertising the Applied Data Science for Geotechnics course.

unterlass@tugraz.at
winkler@tugraz.at

Guests & Visits I

Thursday lecture series - Roddy Cunningham, LLM M.Eng.

On Thursday, March 7th, 2024, RMT had the privilege of hosting Roddy Cunningham, LLM M. Eng., Senior Civil Engineer at CERN'S FCC (Future Circular Collider) project in Geneva, Switzerland, as one of our guests at Graz University of Technology. He delivered an interesting presentation on the ongoing challenges encountered during the feasibility study of the project, with a main focus on site investigation works. The FCC project at CERN aims to explore new frontiers in particle physics, pushing the boundaries of scientific discovery and innovation. Mr. Cunningham's elaborations included the provision of a general project overview, a description of the intended construction methods and a glance at the expected geology in the project region. He also reported on the special organizational structure of the project, which makes the collaboration of different project units from traditional and high-tech sectors possible in the first place.

Thank you very much, Roddy, for providing us with your insights into this truly unique project.

Figure: Mr. Roddy Cunningham (left) and Mr. Manfred Blümel

Faces

...today‘s with our newest student assistant and a master student of our institute.

Paulina Bodner

Hello, everyone! My name is Paulina and last October, I started my bachelor's in civil engineering here at Graz University of Technology. While my academic journey began in geosciences, I've always been captivated by the intersection of natural sciences and engineering, particularly in the field of rock mechanics. I believe that this field not only allows me to indulge in my love for the outdoors but also offers opportunities to make a meaningful impact in preserving our natural environment.

Before diving into civil engineering, I gained valuable practical experience during the previous summers. I had the opportunity to work at a hydroelectric power plant construction site, where I was exposed to countless challenges each day. It was incredibly rewarding to witness firsthand how engineering solutions come to life in real-world scenarios.

As I embark on this exciting journey, I look forward to learning from my peers and mentors, and I'm eager to seize every opportunity to grow and excel in the field of civil engineering. Here's to a fulfilling and enriching academic experience ahead!

Andreas Zani

As a nature enthusiast and then also interested in civil engineering, it was relatively logical for me to choose the Geotechnical and Hydraulic Engineering master's degree after my bachelor's degree at TU Graz. I see it a bit as the keystone in my studies, now I realize what I actually need all the bachelor's subjects for, and at the same time I like the interdisciplinary and varied subjects.

As a South Tyrolean, I've always been fascinated by the mountains, so it wasn't difficult to choose rock mechanics and tunnelling as the focus of my master’s degree. I'm currently working on my master's thesis at the Institute of RMT, which is about a simple method for creating 3D models in tunnel construction, focusing on determining the shotcrete thickness continuously over an entire tunnel section. The result is an as-built state. The whole method is being tested and researched at the Angath test gallery, near Wörgl (Tyrol) one of the BBT's access routes.

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! LINK

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

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

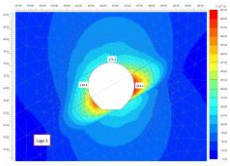
Symposium by the Austrian platform ATC² (Austrian Tunnel Competence Center), a collaboration of Graz University of Technology and Montanuniversität Leoben. The aim of the symposium is to transfer innovative ideas and know-how in tunnelling. In English. In 2024, ATC² will be hosted at the guest location 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.

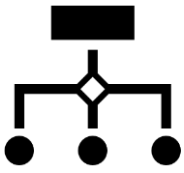
Have a look at our Master‘s Theses II

- **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)**

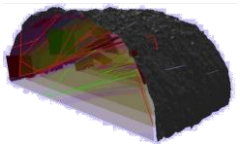
Determination of the mechanical properties of the discontinuities using selected examples of Phyllites in the Central Alps (Switzerland and Austria). Backcalculation on the influence of the schistosity on the tunnel stability. Determining the influence of tunnelling on the activation of potential discontinuities.



- **Rock mass classification systems illustrated in form of a family tree (Master Project)**

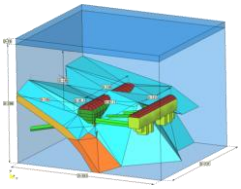
Based on surveys conducted in 2022 and 2023 among the rock engineering community, the dominant rock mass classification systems for underground and slope-related tasks were identified. Using the form of a family tree should help to illustrate the historical development of the different systems and highlight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



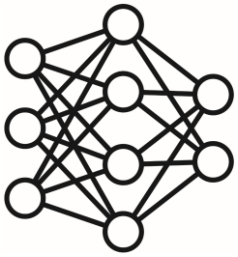
- **A case study: Cavern Stability Analysis (supervisor: T. Marcher)**

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.

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

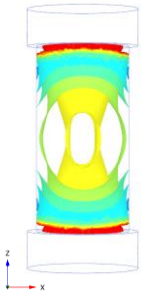
How many exploratory boreholes are necessary in the course of long, deep seated (base-)tunnels? Which insitu and laboratory tests are carried out as standard? How are the explorations distributed between the different project phases? The work focuses on the collection of data based on the experience 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.

Have a look at our Master‘s Theses IV



- **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

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