ROCK REPORT

Mechanics & Tunnelling

Quarterly Newsletter of the Institute of Rock Mechanics and Tunnelling

03 Volume 3
October 2022

RMT

NAWI Graz GEOZENTRUM

TU Graz
Graz University of Technology

MLGT
Machine Learning in Geotechnics

Content

Marcher's Column

The topics of natural hazards and climate change are on everyone's lips. The challenges related to rockfall in the "communal environment" (minor roads, ways and tracks) have not yet been fully understood by the public. A problematic dimension is represented by already used areas that are affected by rockfall events over time. There are considerable differences in the protection possibilities between large infrastructure operators on the one hand and municipalities, tourism associations or private owners on the other. To make matters worse, the risk of rockfall incidences is increasingly aggravated by extreme weather situations and users' lack of knowledge about the effects of alpine natural hazards; the latter in particular also due to a considerable increase in use (keyword „leisure society").

I am looking forward to our Rockfall Symposium 2022 in Schladming on 1 December 2022, which will cover a wide range of topics: from geological/rock mechanical experiences, the influence of climate change and/or forestry to monitoring and risk modelling. Approaches to implement artificial intelligence for rock fall prediction will be discussed and the topic will be rounded off by a legal consideration of civil and criminal liability issues and a discussion of the obligations of the public sector. Details of the event can be found under this LINK.

Directly after this event, we will celebrate "30 years RMT Institute" on Friday December 2nd followed by the Institute's Barbara celebration. We are very much looking forward to seeing you there!

This issue of the Rock Report contains a variety of news from the third quarter of 2022; I would like to draw particular attention to our new research projects: on the one hand, the cooperation with Tasei Corporation, Japan, and ChaMod - HSSR, which provides scientific support for the exploration adit „Rohbaustollen" Angath at the northern extension of the BBT (Brenner Base Tunnel) towards Kufstein of the Austrian Federal Railways (ÖBB).

Enjoy our recent Rock Report,

Glück Auf!

Thomas Marcher

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Title Picture:
Photo of a rock sample from the exploration drilling in Angerberg after a direct shear test - courtesy of ÖBB-Infrastruktur AG

October 17, 2022 – published
Manuel B. Winkler – editor in chief
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Project Focus

Learning from Drilling with the Help of Data Science

"Learning from drilling" – That is what we want together with Taisei Corporation from Japan. With the beginning of September, we therefore started a cooperation project.

Taisei constructed an about 1,100 m long road tunnel. The rock mass predominantly comprises Tuff breccia and Andesite lava. The round length of the full-face with auxiliary bench excavation drive is 1.0 or 1.2 m depending on rock mass classification. Fully automatized drill jumbos create the boreholes for the explosives. During the drilling, the operating system of the drill jumbo records the system's data continuously: orientation of the rig, borehole depth, rotation speed, contact pressure, etc.

Depending on the site conditions like the rock mass structure, strength of geological features, and overburden, the drilling behaviour changes. Theoretically, a clear relation between the conditions and the behaviour must exist. However, engineers usually know the conditions only qualitatively; at least on a global scale. Locally, some characteristics may have been quantified with laboratory or site tests (e.g., strength of more or less intact rock pieces). Because of lack in quantification of all characteristics, the evaluation of qualitative trends replaces the development of a precise relation.

With the evaluation of drilling data, the decision support models can help to reduce the uncertainty by allowing engineers to glance outside the excavation area. Using evaluated trends can make tunnelling more effective, or safer.

At the project with Taisei, we first want to optimise the drill and blast scheme. To do so, we need to identify whether there is a trend between the drilling behaviour, the site conditions, and the specifics of the drill and blast approach (e.g., number of boreholes, amount of explosives). And this is done with the help of Machine Learning (ML). Our data scientist, Alla Sapronova is the project leader. Together with her colleagues, she will analyse the data from selected tunnel sections and apply recent ML techniques.

We will keep you updated about the results!

Your RMT team.

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Research Focus 1/2

ChaMod – HSSR (FFG – Bridge)

… sounds like "Kamod" (Austrian slang word for comfortable)-HSSR. However, the project acronym in this report's title is rather more challenging than comfortable! It is about the Characterisation and Modelling of Hard Soil/Soft Rock (HSSR) material considering anisotropy and swelling. A topic which fits 100% to RMT's main research fields.

But let's start from the beginning. Next year, the Austrian Federal Railways (ÖBB-Infrastruktur AG; ÖBB) starts the construction of the Angath Adit in Tyrol, Austria. In the first place, this adit serves for investigations of the site conditions. Eventually, it will be the evacuation tunnel of a 3 km long section of the Angerberg Tunnel. Cross passages will connect them. Now both the drives of the Angath Adit and the Angerberg Tunnel need to head through the Unterangerberg formation. It predominantly comprises tertiary depositions of sediments being one of the few of inneralpine molasse [1,2]. And it is an alternation of strongly anisotropic clay, marl, and sandstone with varying degrees of weathering. Thus, the engineers have to cope with frequent changes in the strength and stiffness of the rock mass. In addition to being on the verge of the transition from soft rock to hard soil, this material changes its characteristics when exposed to water and some of it features potential for swelling. Along the tunnels, at tunnel level, water pressure of up to 10 bar is expected.

For a research institution, this is a golden opportunity: excavation and observation of HSSR material at the site with its large variety, at a large scale and for a long period of time. And it happens that ÖBB and the Austrian

Picture: Adjustment of measuring sensors on sample to be tested with the triaxial testing device specifically suited for HSSR material © Lunghammer –TU Graz

Research Promotion Agency (Forschungsförderungsgesellschaft mbH, FFG) grant RMT to take this chance. Funded by the programme BRIDGE (FFG project number: FO999895314), ÖBB and RMT will investigate the characteristics of the HSSR material encountered at the Angath Adit extensively throughout the next three years. RMT brings some experience along and is ready to take the challenge:

- Stefan Stauder evaluated the limits of cone penetration tests (CPT) when applied to HSSR material at the site; he also did research on the characterisation and numerical modelling of such materials. Cf., e.g., RockReport issue 1/2020 (p. 7), 2/2020 (p. 9) and 3/2020 (p. 6).
- Manuel Winkler investigates the constitutive modelling of anisotropic rock masses. Cf., e.g., RockReport issue 1/2021 (p. 3).
- Recently, RMT has supervised following Master's theses: [3, 4, 5, 6]
- And RMT's laboratory operates a special triaxial testing facility perfectly adjusted to test HSSR material. Cf., e.g., RockReport issue 2/2020 (p. 6) and 1/2021 (p. 5).

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Research Focus 2/2

ChaMod – HSSR (FFG – Bridge)

Due to the relevance of HSSR material in today's constructions, in 2020, RMT organised a mini symposium dedicated to the topic. Interesting contributions from RMT staff members and from external experts can be found in the symposium proceedings [7].
Back to the project. In the adit, our researchers will monitor the material behaviour. They will also evaluate information and data from experimental (in situ, laboratory) and observational campaigns. With the knowledge gained, recent numerical modelling approaches will be calibrated and tested upon their applicability. Eventually, the project shall result in a detailed description of the fundamental material specifics in their natural variability, a pool of information and data of high quality, and recommendations for characterising and modelling of HSSR material. In addition, it shall contribute to a clear and meaningful approach to differentiate between rock, HSSR material, and soil. The long-term goal of the project consortium is to reduce uncertainties in the planning and execution of structures on and in HSSR material and to optimise them.

Looking forward to a fruitful (hard, or soft) and long-lasting cooperation,

Your RMT team.

[1] *Sommer, P., Erharter, G., Sedlacek, C., Strasser, M. und Poscher, G.: Geologische Erkun-dung und Trassenplanung im gasführenden Tertiär des Unterinntals, Tirol. Fachsektionstage Geotechnik: Interdisziplinäres Forum. Würzburg, 2019.*

[2] *Ortner, H. und Sachsenhofer, R.F. 1996. Evolution of the Lower Inn Valley Tertiary and constraints on the development of the source area. In: Wessely, G. and Liebl, W. (eds), Oil and Gas in Alpidic Thrustbelts and Basins of Central and Eastern Europe, EAGE Special Pub-lication No. 5, pp. 237–247.*

[3] *Işkin, F. 2020. Anisotropic Evaluation of the Brenner Base Tunnel Database with a Special Focus on the Innsbruck Quartz Phyllite, Department of Engineering Geology and Geotech-nics, Budapest University of Technology and Economics, Budapest, Hungary.*

[4] *Harmuth, M. 2020. Identifizierung der Grenzen von Drucksondierungen in halbfesten bis festen Böden (Hard Soil – Soft Rock). Master Thesis, Graz University of Technology, Institute of Rock Mechanics and Tunnelling, Graz, Austria.*

[5] *Thurner, F. 2021. Modified Quality Assessment of Dry Deep Soil Mixing Columns in Sweden. Master Thesis, Graz University of Technology, Institute for Rock Mechanics and Tunnelling, Graz, Austria.*

[6] *Wallner, C. 2020. Numerical analysis of "hard soil – soft rock" by utilizing the PLAXIS "Concrete Model". Master Thesis, Graz University of Technology, Institute for Rock Mechan-ics and Tunnelling, Graz, Austria.*

[7] *Marcher, T. (eds). 2020. HSSR Minisymposium, Proceeding Book, Graz University of Technology, NAWI Graz Geocenter.*

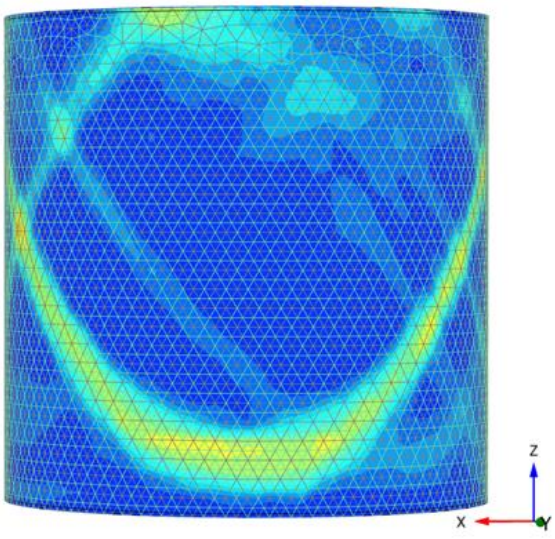

Figure: Numerical simulation of a triaxial test on HSSR material showing the generation of shear bands

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Rigorosum Klammer

This summer, Angelika Klammer finished her doctoral program with distinction. On 22 August 2022, she had her “Rigorosum”, which is the final presentation and defense of a doctoral thesis. It consists of two parts. First, the doctoral student has 30 minutes time to present his/her thesis and then there is an examination of one hour by a commission of three professors. Prof. Dr. Wulf Schubert (Graz University of Technology, Graz, Austria - supervisor and first examiner), Prof. Dr. Reşat Ulusay (Hacettepe University, Ankara, Turkey - second examiner) and Assoc. Prof. Dr. Franz Tschuchnigg (Graz University of Technology, Graz, Austria - chair of commission and third examiner) formed the commission at the Rigorosum of Angelika Klammer. Her thesis has the title “Investigation of the influence of grain-scale heterogeneity on strainburst proneness using Acoustic Emission Testing”. Angelika Klammer will remain part of the RMT-team for the time being and then join the “real” working world.

Picture: Angelika Klammer, Dipl.-Ing. Dr.techn. BSc

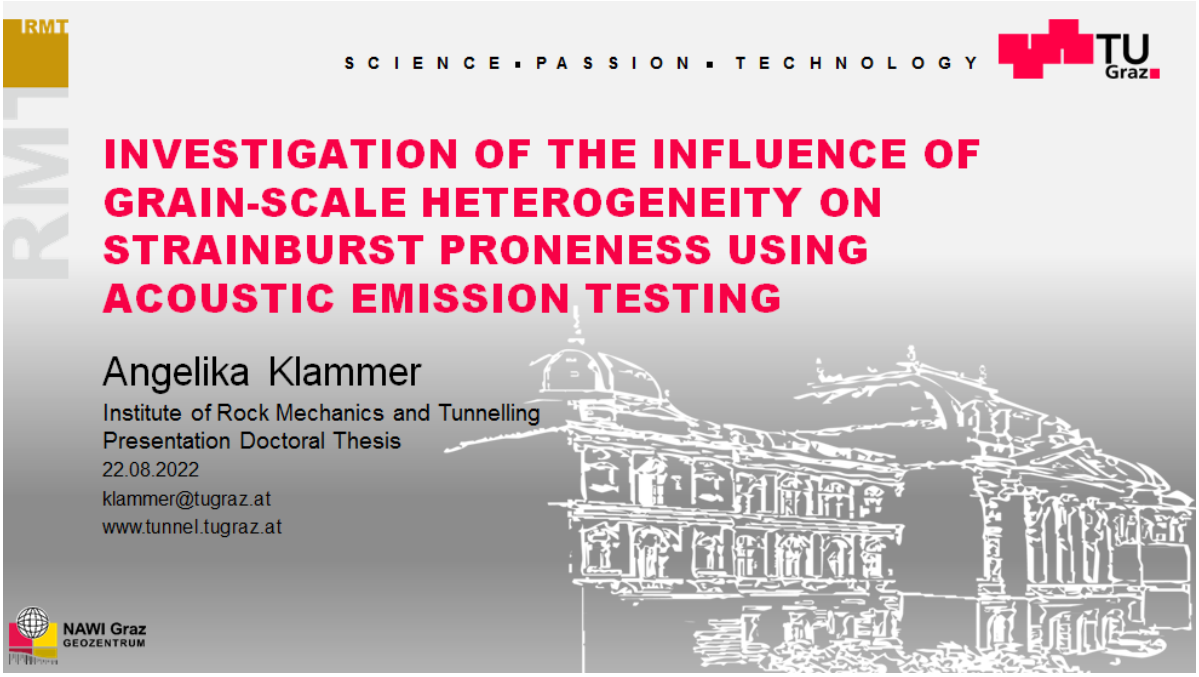

Figure: Title page of Angelika‘s presentation at her PhD defensio

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Reader‘s Contribution

Help us create the "World Map of Rock Mass Classification Systems"!

Authors: *Georg H. Erharter (RMT & Norwegian Geotechnical Institute), Tom. F. Hansen (Norwegian Geotechnical Institute), Shengwen Qi (Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing, China), Neil Bar (Gecko Geotechnics, Cairns, Australia), Thomas Marcher (RMT)*

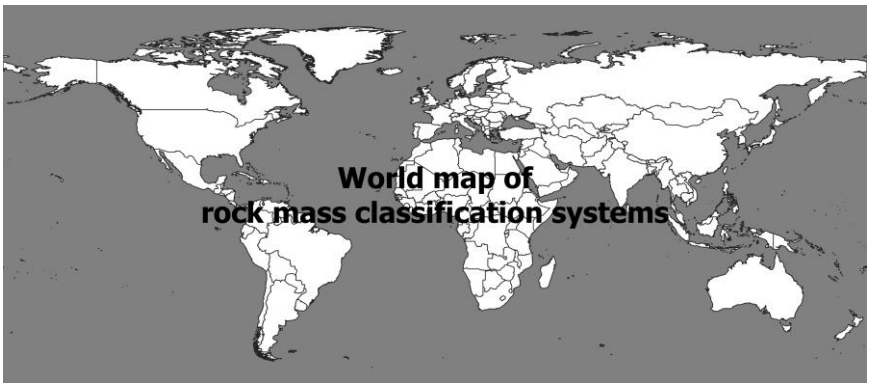
To carry out engineering design of underground- and surface excavations, rock mass classification is imperative. The Rock Mass Rating, Q-system, Basic Quality (BQ), Geological Strength Index (GSI) or NATM-style rock mass type characterization are just a few approaches towards quantifying and classifying rock mass nowadays. The wide range of available systems is symptomatic for the complexity of the underlying challenge of rock mass classification. Ongoing technical debates among scholars and professionals show that the community has not yet converged to an optimum solution to that problem.

As part of a submission to the ISRM 2023 congress we want to assess which rock mass classification systems are predominantly used around the world and for which application. This will help us to assess the state of the art of rock mass classification and the results will be published at the congress.

Please help us create the "world map of rock mass classification systems" by filling out a short survey to tell us what rock mass classification system you apply to your projects! If you apply multiple systems, work on multiple project types or in different countries, please feel free to fill out the survey multiple times. Survey is open until 30 November 2022.

Use this link or the below given QR code to access the survey:

https://forms.office.com/r/7sDX6UvM60



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Publications & Presentations I

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

Identifying Rock Loads on TBM Shields During Standstills (Non-Advance-Periods)
Paul J. Unterlass, Georg H. Erharter, Thomas Marcher (Published in Geotechnical and Geological Engineering 2022 – Open Access)

Tunnel boring machine (TBM) operational data is mostly analysed with respect to data that was recorded during the advance of the TBM. Focusing on data that was recorded during standstills of a gripper TBM, we analyse rock loads that were passively recorded in the cylinders of a small roof support shield. These roof support cylinders are situated beneath the TBM's shield – extending it against the rock mass during non-advance periods. Equipped with pressure sensors, they enable the unique opportunity of logging rock load variations throughout the tunnel. Hence due to the big amount of resulting data, techniques of unsupervised machine learning (i.e. cluster analysis) are used to automatically pre-process the TBM operational data. Furthermore, regression analysis is used to determine sections of the tunnel where rock loads are mainly occurring on the left or right side respectively. The data driven analysis shows that the main rock loads are occurring on the right side of the TBM which is in good accordance with observation from the construction site, as well as numerical models from literature. This paper contributes towards the understanding of rock load conditions in anisotropic rock masses recorded during the drive of a deep hard rock tunnel.

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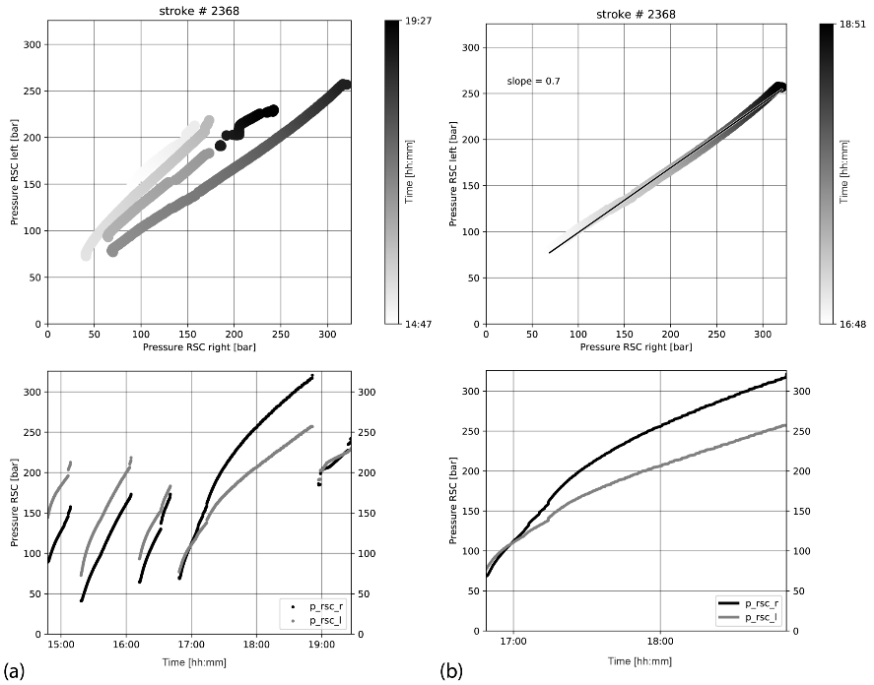

Figure: Plot of stroke # 2368, in the upper row the pressures in the RSCs left and right are plotted against each other, whereas in the lower row the pressures are plotted against time. The left column (a) shows all pressure increases during stroke # 2368 and the right column (b) only shows the longest increase.

Publications & Presentations II

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

Conference talks at the 4th ICITG
Paul J. Unterlass & Alla Sapronova, 4-5 August 2022, Singapore (online)

The institutes research focus on machine learning in geotechnics was represented by two conference talks at the 4th International Conference on Information Technology in Geo-Engineering. Paul Unterlass and Alla Sapronova, both members of the machine learning in geotechnics (MLGT) workgroup at TU Graz, were given the chance to present and discuss their latest research amongst a highly qualified audience of scientists, developers and engineers. Mr. Paul Unterlass held a talk about an Artificial Neural Network based Q-system classification of TBM operational data. Due to the sequential nature of TBM operational data a Long-Short-Term Memory (LSTM) ANN architecture was used to predict Q-values (a rockmass classification system) on a dataset form Norway's Ulriken Tunnel. The results showed that the used ANN is well capable of predicting Q-values directly and thus could be used for rockmass classification in tunnel projects where closed shield TBMs are used.

Mrs. Sapronova's talk dealt with the sparsity and imbalance in geotechnical datasets which become a limiting factor when using such data for reliable and accurate machine learning based models. Different oversampling approaches, extending and enriching the sparse and imbalanced datasets are tested. Focus was set on comparison of commonly used oversampling techniques (i.e., SMOTE and ADASYN) and deep learning techniques such as generative adversarial networks (GANs). Results show that the reformed, balanced and enhanced datasets can be effectively used for predictive machine learning models.

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Conference talks at the ISIC International Conference
Paul J. Unterlass & Alla Sapronova, 6-9 September 2022, Guimarães, Portugal

The institutes research focus on machine learning in geotechnics was again represented by two conference talks at the ISIC International Conference – Trend on Construction in the Post-Digital Era. Mr. Paul Unterlass' contribution covers a generative adversarial network (GAN) based approach of generating synthetic geotechnical data for further applications in research and education. Such synthetic datasets show similar characteristics as the original data, but still present unique samples with no connection to the original data. They can therefore be made available publicly to the geotechnical community allowing the comparison, benchmarking and pre-training of machine learning models for geotechnical purposes.

Mrs. Sapronova's work deals with a new approach for predicting geological information ahead of the tunnel face by using an ensemble of machine learning methods, combined with oversampling (dataset balancing) techniques. Data from seismic explorations collected with Amberg Technologies' TSP (tunnel seismic prediction) system is clustered in an unsupervised manner and obtained cluster information is then integrated with various geological labels. In the end a supervised machine learning model is trained to predict the rock mass classes and/or the rock types.

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Publications & Presentations III

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

Machine learning – An approach for consistent rock glacier mapping and inventorying – Example of Austria

Georg H. Erharter, Thomas Wagner, Gerfried Winkler, Thomas Marcher (Published in Applied Computing and Geosciences – Open Access)

Rock glaciers (RG) are landforms that occur in high latitudes or elevations and — in their active state — consist of a mixture of rock debris and ice. Despite serving as a form of groundwater storage, they are an indicator for the occurrence of (former) permafrost and therefore carry significance in the research for the ongoing climate change. Therefore, many RG inventories were established in the past years to investigate permafrost and quantify water storages. Creating these inventories, however, usually involves manual, laborious, and subjective mapping based on aerial image - and digital elevation model analysis. We propose an approach for RG mapping based on supervised machine learning (ML) which can help to increase the mapping efficiency and permits rapid RG mapping in vast and not yet covered areas. The input to the ML models consists of orthophotos and slope maps of digital elevation models as input. The output is derived from a recently published RG inventory of the Austrian Alps that features 5769 individual RGs. Based on this, the ML models have learned the average expert opinion and the generated RG map can be used to increase the consistency and completeness of already existing RG inventories. Moreover, this ML approach might be valuable for other landform mapping tasks beyond rock glaciers (e.g., other mass movements).

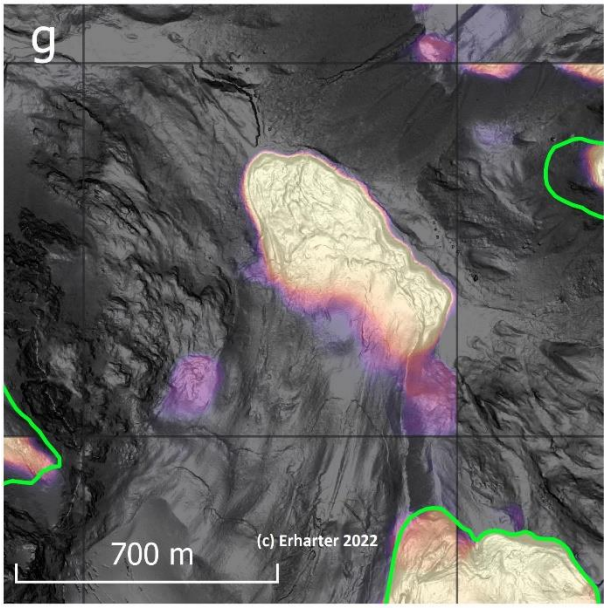

Figure: Example of a potential rock glacier that was found by the machine learning algorithms.

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Publications & Presentations IV (1/2)

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

Session on „AI in Geotechnics“ at the Geomechanic Colloquium 2022 in Salzburg
Thomas Marcher (Session Chair)

It was an honour for me to chair the half-day session on "AI in Geotechnics" at this year's GMC in Salzburg. The session was a complete success with highly interesting contributions and numerous requests to speak from the audience.

AI is part of our everyday life: e.g., speech recognition, facial recognition, use of search engines or social networks and much more. What is AI actually? In my opinion, the ability of a machine in the sense of a computer to carry out tasks that requires „intelligent actions“. Machine Learning (ML), as a subbranch of AI, is a technique in which "machines learn from data" - a process that is absolutely not new. What is new is the combination of enormous computing power, access to big datasets and new, more efficient algorithms. In my opinion, this has not only led to a current hype, but will also permanently change our work as geotechnical engineers / tunnel engineers. An artificial neural network consist of (several) layers filled with neurons (similar to a human brain) and the actions of individual neurons are not predetermined. Only the settings of the "adjusting screws“ (i.e., weights and biases) in such a network are actively "trained". In my opinion, "artificial intelligence and learning machines" are the wrong terms because they suggest independent actions! The implementation of ML techniques will support us in a goal-oriented and problem-oriented way to "handle" large amounts of data. Hence, AI should primarily be seen as a "tool" to extract and understand information in our data, making our work easier and more efficient!

(continued on next page)

Picture: Presentation of Josephine Morgenroth during the session on “AI in Geotechnics”.

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Publications & Presentations IV (2/2)

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

Session on „AI in Geotechnics“ at the Geomechanic Colloquium 2022 in Salzburg
Thomas Marcher (Session Chair)

(continuation from previous page)

"AI in geotechnics" is coming to all of us! In order to apply ML you don't have to be a Data Scientist. Similar to the development and introduction of numerical methods in geotechnical engineering and tunnelling (e.g. FEM/FDM) over the last 20 years, AI/ML has „developers/data scientists“, „software producers/manufacturer“ and „(end-)users“. As geotechnical/tunnelling specialists at the university, we feel responsible on the one hand for continuously testing the possibilities, making recommendations and publishing results. On the other hand, it is crucial that students are trained in this field at an early stage and in a sustainable manner.

Thomas Marcher

RMT’s contributions in the colloquium session “AI in Geotechnics”:

- **Practical recommendations for machine learning in underground rock engineering: On algorithm development, data balancing and input variable selection**
  (J. Morgenroth, P.J. Unterlass, A. Sapronova, U.T. Khan, E.H. Perras, G.H.Erharter, T. Marcher)
- **Towards optimized TBM cutter changing policies with reinforcement learning**
  (G.H. Erharter, T.F. Hansen)

Picture: Presentation of Georg Erharter during the session on “AI in Geotechnics”.

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Young Members Austria (1/2)

RMT member Thomas Geisler joined the steering committee of Young Members Austria

Thomas Geisler, a member of the institute of Rock mechanics and Tunnelling is active in the Steering Committee of the Young Members Austria. He was able to travel to the World Tunnel Congress in Copenhagen in September, to vote on behalf of Austria as a delegate of Young Members Austria in the election of the ITAym international Steering Committee.

In addition to the scientific programme, the social events were not neglected. Exciting conversations - as well as cooperations - with other young member groups (e.g. STUVA-YEP) could be established.

Furthermore, Andreas Granitzer, who is also a member of the Steering Committee and assistant at the neighbouring Institute of Soil Mechanics, Foundation Engineering and Computational Geotechnics established a cooperation with the British Geotechnical Association Early Career Group during the 11th International Symposium on Field Monitoring in Geomechanics in London.

(More detailed information of the Young Members Austria can be found on the following page)

Picture: Signing of cooperation agreements between YM Austria and STUVA-YEP (left) and BGA ECG (right)

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Young Members Austria (2/2)

Introduction of Young Members Austria

The Young Members Austria are an inter-organisational team of young engineers under 35 years of age from all sub-disciplines of geotechnics. This includes soil & rock mechanics, numerics, tunnelling, foundation engineering and engineering geology, to name a few disciplines in which Austrian engineers have been pioneering. This network is supported by ISSMGE, ISRM & ITA – AITES.

Picture: The YM Austria Symposium 2022 in Vienna .

The Young Members Austria stand for:

- Networking in relaxed atmosphere
- Promotion of next generation engineers
- Intergenerational dialogue
- International cooperation
- Science communication
- Green engineering, gender competence & digitization

What to expect from the Austrian Young Members:

- Exchange in a cohesive network consisting of over 200 like-minded people
- Events with positive error culture
- Continuing education based on expert lectures
- Platform to develop rhetorical skills
- Award ceremony for Master's theses

The Young Members Austria are pleased to announce the YM Symposium on April 12th, 2023, which will be held at the Graz University of Technology. More information will follow soon! We'd love to welcome you there!

More information can be found on Linkedin

or https://www.oegg.at/de/sektionen

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Faces

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

Andreas Buyer (Alumni)

I finished my bacherlor's and master's degree at the Technical University of Munich. During my master's thesis the question arose about a possibility to automatically extract geological structures in outcrops. The basic idea of my PhD was born and I started my research at the Institute of Rock Mechanics and Tunnelling in Graz in 2015.

In my research, I focused on an automated analysis of geologic structures in natural and artificial rock faces using digital images and 3D point clouds. The gained information was implemented in numerical software for geotechnical stability analyses.

After finishing my PhD, I started as an engineering geologist at the consulting company GDP ZT GmbH where I profited from my education at the TUM as well as my time at the RMT. Now I work hands on as well as digitally to map and characterize rock masses in an engineering aspect, while profiting from my education from two different universities but also my researches and the input of my supervisors.

It was a very interesting life period at the RMT in Graz I wouldn't like to miss.

Ali Yaz

I enrolled for the bachelor's program of Civil Engineering at Istanbul Technical University (ITU) in 2017 from which I will graduate next February. During my studies, I had a chance to take courses from different fields of civil engineering. However, Soil Mechanics and Foundation Engineering are two of the courses which attracted most of my interest.

Previously, I had a chance to be a site intern at Batumi Highway Road Project. In the scope of this project, tunnel excavations, retaining walls and pile foundations of bridge columns were carried out. Moreover, I gained insights into NATM tunnelling during my internship. Last spring, I have applied for a trainee program at the Institute of Rock Mechanics and Tunnelling (RMT) via IAESTE and started to work for RMT in July this year. So far, I have been involved in the 3D design of artificial rock samples. Currently, I am focusing on the analytical computation of displacements and stresses due to excavation of a tunnel in an anisotropic rock mass with arbitrary cross-section under supervision of Mr. Winkler. This trainee program offered by RMT allows me both, to broaden my knowledge in this field and improve my programming skills.

Diary of Events

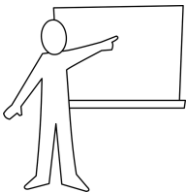
> Mini-Symposium “Rockfall Risk”
Schladming, Austria, (2022/12/01)

The symposium "Rockfall" will shed light on experiences and approaches to this topic from various disciplines. The spectrum ranges from engineering geology and rock mechanics to influences related to climate change, modern processing methods, possible further developments with the help of artificial intelligence, and legal liability issues. National and international experts will provide technical contributions and institutions will present their approaches (Further information - Link).

> 30th Anniversary Celebration of RMT followed by “Barbarafeier”
Graz, Austria (2022/12/02)

It has been 30 years since the Institute of Rock Mechanics and Tunnelling was founded in the year 1992. This must be celebrated and therefore a 30th anniversary celebration will take place at TU Graz on 2nd December 2022 (Start: 17:00 o’clock). After the anniversary celebration our yearly Barbarafeier will take place starting at 19:00 o’clock. Hope to see you there. Further information regarding the program and registration will follow on our website - Link.

> Lecture „Die Herausforderungen an den landesgeologischen Dienst - Fallbeispiele aus Kärnten“ (in German)
Graz, Austria (2023/01/26, 17:15 CET)



Lecture by the federal geologist of the province of Carinthia Mag. Franz Goldschmidt. The lecture will be in German and will take place in the lecture Room HS L (Lessingstraße 25/1, 8010 Graz) . Registration via email addressed to tunnel@tugraz.at .

> ATC²-Symposium 2023
Graz, Austria (2023/12/01)

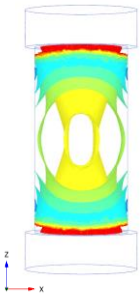
Symposium by the Austrian platform ATC² (Austrian Tunnel Competence Center), a collaboration of Graz University of Technology and Montanuniversität Leoben. The aim of the symposium is to transfer innovative ideas and know-how in tunnelling. In English. The topics of the upcoming events are: Shallow Tunnelling, Urban Tunnelling incl. Metro Tunnels and Stations. Further information can be found on the ATC² homepage (update in progress).
http://austrian-tunnel-competence-center.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

Have a look at our Master‘s Theses I

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

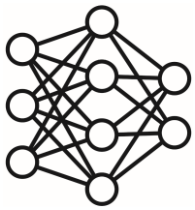


- **Numerical and experimental investigation of rock anisotropy**

(supervisors: T. Frühwirt, M. Winkler)

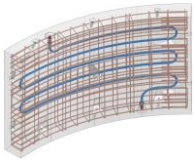
Rock is a complicated material, for example it is very often anisotropic making its’ deformational and strength characteristics dependent on the loading direction. To learn more about this phenomenon, numerical and experimental studies need to be carried out.

- **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).

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



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

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

- **Significance of thermomechanical processes on rockfall hazards (supervisor: R. Kienreich)**

© Rainer Kiernreich

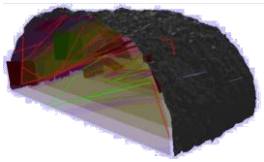
Thermomechanical processes, along with interface structure and mountain water conditions, are considered primary triggers of rockfall phenomena. The rock mechanical hypothesis is that numerous microcracks form more or less statistically distributed cavities. In the precipitation-intensive period in the following fall, this causes intensive water input, which leads to an increased exceeding of the stability, i.e. rockfall. In order to get a better understanding of the phenomenon, the field data - precipitation in combination with the temperature course of the accumulation of rockfall events should be compared. The different material behavior of carbonate and crystalline rocks is to be described from literature data or possibly laboratory tests.

Have a look at our Master‘s Theses II

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

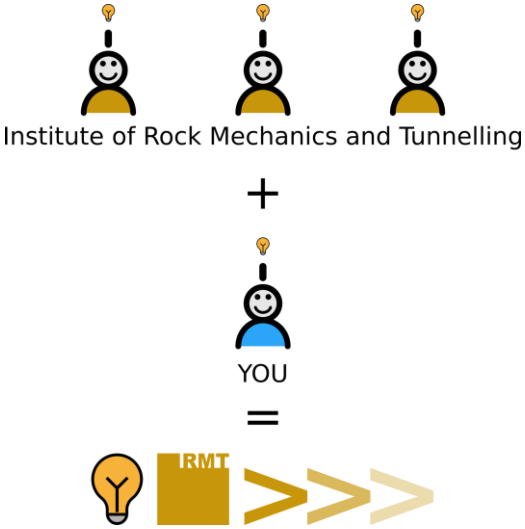
Advances in engineering equipment that is now capable to delivers massive in-situ data at runtime, open the possibility of employing data analysis and data-driven modeling to ensure proactive risk management and optimize the work. Although a large number of features characterize the geotechnical data, 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.

- **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.

Positions at RMT



Open Positions

- We are looking for a technician with interest in mechanical and electrical engineering to support our laboratory team. The job offers plenty of variety as it includes diverse tasks ranging from operating high-end measuring equipment to skilled manual work such as drilling and sawing of rock cores. A special focus will be on mechatronic and electrical engineering to set-up, retrofit and further develop our laboratory testing equipment. This challenging full-time job may be started before the end of this year, the sooner the better. For more information just send us your contact details via tunnel@tugraz.at.

JOIN RMT – we'd love to welcome you.

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UNIVERSITY OF GRAZ
Institute of Earth Sciences
Institute of Civil Law, Foreign Private Law and Private International Law

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Brenner Base Tunnel

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