ROCK REPORT

Mechanics & Tunnelling

Quarterly Newsletter of the Institute of Rock Mechanics and Tunnelling

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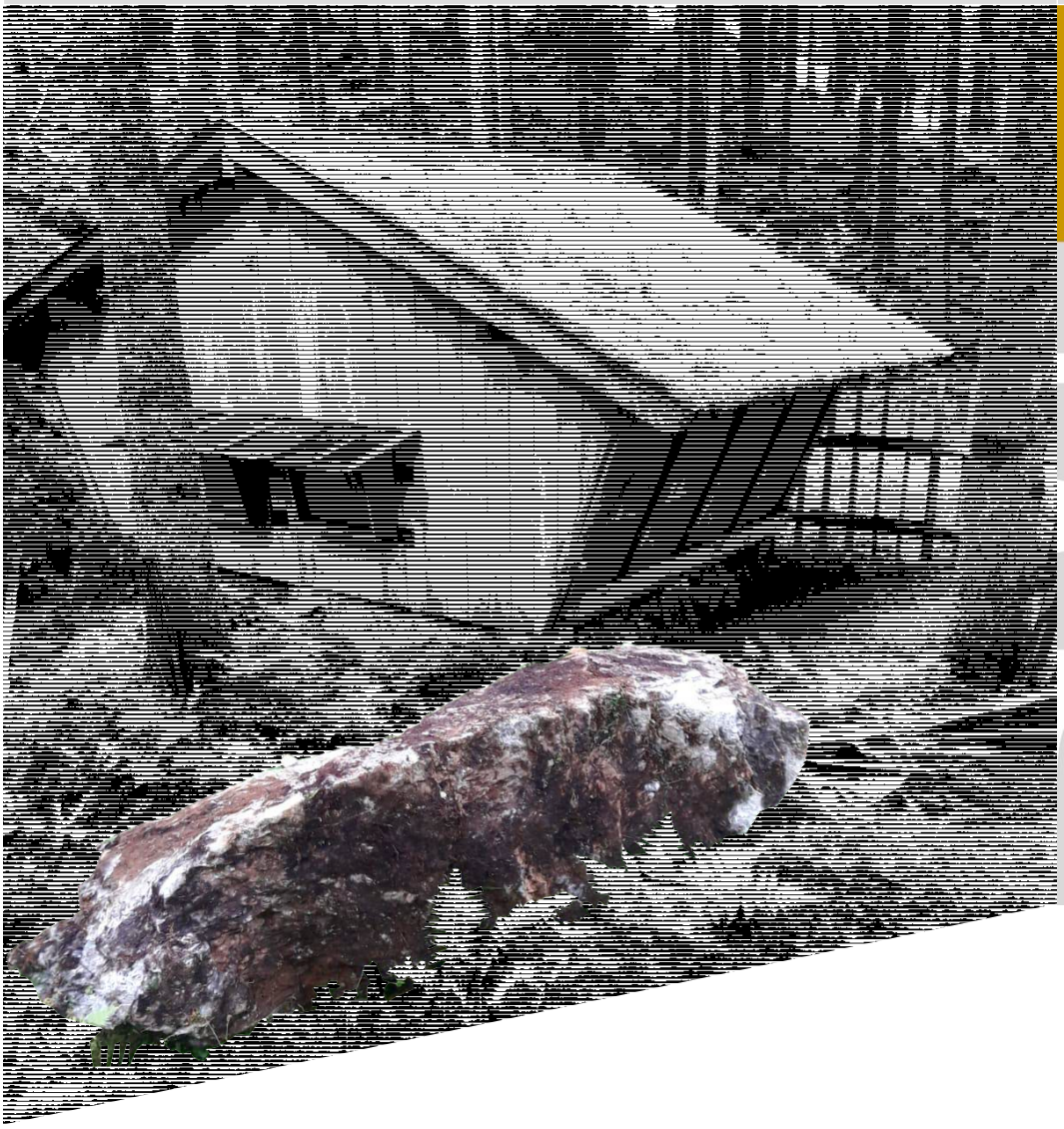
November 2021

RMT



NAWI Graz GEOZENTRUM

TU Graz Graz University of Technology

MLGT Machine Learning in Geotechnics

Content

Marcher's Column

Dear Friends of the Institute,

In this issue - despite many pandemic-related problems - I would like to focus on positive developments at our institute.

It is a great pleasure for me that Georg Erharter was the first doctoral student to graduate under my supervision at the institute. Mr Erharter started at the Institute with me in September 2018. Due to the rapid activation of national and international contacts, a lively research exchange and trips (especially in 2019) to Norway, UK and Spain could be undertaken. A number of publications in high ranking journals followed and laid the foundation for an excellent cumulative PhD thesis.

Despite the pandemic, we try to maintain our international network. A very pleasing example of this is the cooperation ceremony online with Universiti Teknologi Malaysia (UTM). We look forward to a lively exchange in research and teaching!

Fascinating for me is how an interdisciplinary, regional research project (Rock Fall Risk - STEIRIS) attracts young students to complete their thesis in this field. In a very short time we were able to set up a young team from different institutes at Graz University of Technology and the University of Graz.

In the end: it is a real pity that after 2020 we had to cancel our traditional institute Saint Barbara celebration again in 2021. It is my conviction that only solidarity and joint action can bring us out of this crisis and enable us to enjoy social life again!

Glück Auf and stay healthy!

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Title Picture:
A silent witness („Stummer Zeuge") as an indicator of a potential rock fall hazard in the Untertal Valley (Styria)
© Mag. Rainer Kienreich – Head of Technical Department of the district Liezen (Office of the Styrian Provincial Government)

26. November 2021 – published
Manuel B. Winkler – editor in chief
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Project Focus I

Another great university from Malaysia cooperates with us: UTM

Figure 1. Prof Marcher talking about fault zone management to Malaysian academics and experts at the Institute of Energy Infrastructure (UNITEN) in Kajang, Malaysia, on December 11th, 2019.

In the last issue of the Rock Report [LINK], we reported about the visit of Universiti Tenaga Nasional (UNITEN) in Malaysia end of 2019. Part of the visit has been also a series of lectures by RMT:

- Prof Marcher: Long infrastructure tunnels: trends and challenges for the future
- Mr Kluckner: ShapeMetriX: 3D imaging and assessment technology
- Prof Marcher: Risk assessment in tunnelling: Fault zone management
- Prof Marcher: Single shell lining design

We had 17 participants (Figure 1). And one of them was Ms Assoc Prof Ir. Dr Rini Asnida Binti Abdullah from Universiti Teknologi Malaysia (UTM). UTM is located in Johor, the southernmost federal state of Peninsular Malaysia (West Malaysia), next to the border of Singapore.

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Assoc Prof Rini also contributed to the collaboration discussions after the lectures together with colleagues from UNITEN. Before her flight back to Johor, and before our flight back to Austria, she surprised us with a visit to the Putra mosque (Figure 2 on page 4). She told us a lot about Malaysian traditions and their culture, and ensured that our journey ends with nice memories of her country.

Assoc Prof Rini is an academic of the Department of Geotechnics and Transportation at the School of Civil Engineering and also a manager at the Academic Leadership and Professional Development Unit at UTM.

On November 18th, 2021, RMT officially signed a Letter of Cooperation between RMT and the School of Civil Engineering at UTM (Figure 3 on page 4). Signatories have been Prof Dr Norhazilan Mohd Noor, Chair of the School of Engineering, and Prof Thomas Marcher, head of RMT.

Project Focus II

Together with her colleagues and RMT, Assoc Prof Rini plans to design micro-credential courses on rock mechanics and tunnelling, which will be the first such course to be offered in Malaysia. The focus of collaborative research was also discussed.

It will involve the predictions of settlement during tunnelling using Machine Learning, and the health assessment of existing tunnels in Malaysia.

RMT looks forward to this cooperation and is very happy to have UTM board the ship, sailing towards a more sustainable future.

"Stay safe and keep rocking!

Alexander Kluckner

Figure 2. Left: Group photo with Ms Assoc Prof Ir. Dr Rini Asnida Binti Abdullah (UTM) at the Putra Square in the city of Putrajaya (Malaysia). In the background the Perdana Putra, the Prime Minister's Department of Malaysia. Right: The Putra mosque, constructed in the late 90s.

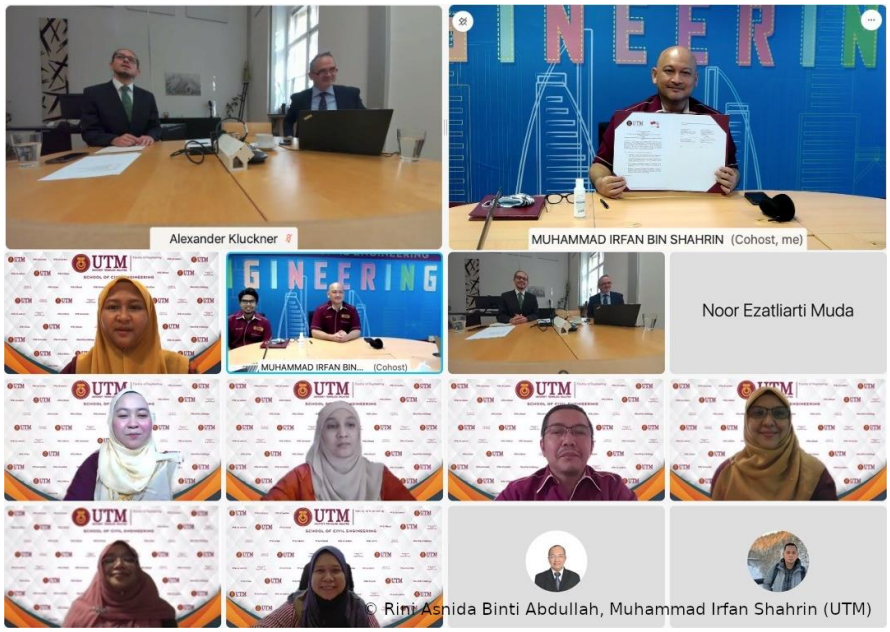

Figure 3. Online group photo during the signing ceremony.

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Research Focus I

Rock fall: an everyday and pervasive problem

Rock fall is a company in the UK fabricating the "most innovative safety footwear". But —in contrast to the unintended promotion of this footwear company—, rock fall is also a natural hazard in alpine regions.

Rock fall endangers animals, infrastructure, and people. Thus, the topic has been and is investigated by many researchers. Some recent studies also relate rock fall events to the climate change (e.g., —randomly selected— [1], [2]). As it is an everyday problem, it not only concerns researchers but also officials, infrastructure operators, and the tourism industry. Regarding the latter, for example, some authors claim that *"for destinations in the mountains, it is of great importance to identify and communicate risks in order to prevent negative effects for tourism"* ([4] and [5] in [3]).

The municipality of Schladming confronted us with the same problem. Unlike infrastructure operators, who must reduce the risk of rock fall or reduce the damage such an event can cause at each facility by mitigation measures, municipalities do not have the resources to do so along all walking and biking tracks and trails they are responsible for. Besides, it would be unattractive to tourists and catastrophic to the wildlife if we would, for example, envelop all rock surfaces with wire nets.

We need another solution and started the project "STEIRIS". Its aim is to elaborate an easy-to-use approach for responsible parties, allowing for a transparent and complete survey and assessment of natural rock fall hazards and events along municipal roads and for the selection of economically reasonable and sustainable mitigation measures. The project name abbreviates the German word for rock fall risk (= Steinschlagrisiko). It also describes the region the project's research covers (the state of Styria; in German: Steiermark) and from which currently all partners are:

Clients:

- Municipality of Schladming [LINK, in German only]
- RML Regionalmanagement Bezirk Liezen GmbH (regional association) [LINK, in German only]

Research facilities:

- Graz University of Technology (TU Graz), Institute of Rock Mechanics and Tunnelling (Prof Thomas Marcher, Mr Alexander Kluckner, Mr Rainer Kienreich) [LINK]
- Graz University of Technology (TU Graz), Institute of Construction Management and Economics (Prof Christian Hofstadler, Dr Markus Kummer) [LINK, in German only]

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Research Focus II

Rock fall: an everyday and pervasive problem

- University of Graz (Uni Graz), Institute of Civil Law, Foreign Private Law and Private International Law (Prof Walter Doralt, Assoc Prof Peter Schwarzenegger) [LINK]

Sponsor:

- Bauunternehmung Granit Gesellschaft m.b.H [LINK]

The variety of the partners highlights the interdisciplinarity the solution requires. It is not just geology and geotechnics; it is also about "How to assess the risk?", "Self-responsibility of the users of municipal roads?", "Who is responsible according to the national law?", "How to make the evaluation and decision process transparent and efficient?" etc. Anyway, the project team does not aim to develop, e.g., new survey techniques or mitigation measures, but attempts to combine well-established approaches for the need of the clients.

The project starts at a regional level. However, rock fall is also important in other countries (e.g., Bavaria, Switzerland, South Tyrol). Depending on the project results and the interest of others, the project may extent to the national or even transnational level within the next years. We know that we then have to change the project name ☺

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Last but most important, let me list the students who help us with the research (women first; alphabetical order): Ms Antonia Neubauer (Uni Graz), Ms Jennifer Peine (TU Graz), Mr Franz-Josef Friedl (Uni Graz), Mr Florian Greinix (Uni Graz) and Mr Patrick Ulbl (TU Graz).

"Stay safe and keep rocking!

Alexander Kluckner

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[3] Pröbstl-Haider, U., Hödl, C., Ginner, K. and Borgwardt, F. 2021. Climate change: Impacts on outdoor activities in the summer and shoulder seasons. Journal of Outdoor Recreation and Tourism, Vol. 34, p. 16. DOI: https://doi.org/10.1016/j.jort.2020.100344

[4] F. Braun. 2009. Sommer-Bergtourismus im Klimawandel: Szenarien und Handlungsbedarf am Beispiel des hochalpinen Wegenetzes. PhD thesis, University of Natural Resources and Life Sciences, Vienna, Austria.

[5] Pröbstl-Haider, U., Dabrowska, K. and Haider, W. 2016. Risk perception and preferences of mountain tourists in light of glacial retreat and permafrost degradation in the Austrian Alps. Journal of Outdoor Recreation and Tourism, Vol. 16, pp. 66—78. DOI: https://doi.org/10.1016/j.jort.2016.02.002

Research Focus III

Rock fall: an everyday and pervasive problem

TU Graz Graz University of Technology
RMT Institute of Rock Mechanics and Tunnelling
iBBW Institute of Construction Management and Economics
UNIVERSITÄT GRAZ UNIVERSITY OF GRAZ Institute of Civil Law, Foreign Private Law and Private International Law
RML REGIONALMANAGEMENT BEZIRK LIEZEN
BAUUNTERNEHMUNG GRANIT GRAZ
Schladming

… and for those looking for some nice pics, please have a look at the figure below!

Figure: Rock fall hazard close to the Ursprungalm in the alpine region of the municipality of Schladming. Left: Photograph taken from helicopter on August 9th, 2021; Centre: Installation of the blasting charge by experts on October 18th, 2021; Right: Photograph of the explosion taken from the opposite side of the valley. Copyright: Rainer Kienreich (Graz University of Technology, Institute of Rock Mechanics and Tunnelling)

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Recent RMT Guests I

W. Wittke


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On the 24th of September Prof. Dr.-Ing. Dr.-Ing. E. h. Walter Wittke and two of his daughters (Bauass. Dr.-Ing. Bettina Wittke-Schmitt and Dr.-Ing. Patricia Wittke-Gattermann), who are his partners in WBI company, gratefully paid our institute a visit. Thereby each institution (RMT and WBI) had the chance to introduce itself and give insights into its current fields of activities and research. Furthermore, the potential for a future cooperation between RMT and WBI was evaluated. A final group photo taken during a visit of our rock mechanics laboratory, following the very interesting discussion round, testifies to a successful “get to know” of both institutions.

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R. Fuentes


© Raul Fuentes

In the end of September Univ.- Prof. Dr. Raul Fuentes visited the Institute of Rock Mechanics and Tunneling as he agreed to be the second examiner of the Rigorosum of Georg Erharter (see article on page 13). After different research positions at the University College London, University of Leeds and the Universitat Politècnica de València he currently holds the position as head of the Chair of Geotechnical Engineering and Institute of Geomechanics and Underground Technology (GUT) at RWTH Aachen. His research topics cover different fields of digitalization in geotechnics with a special focus on robotics, about which he also gave a presentation while he was staying at Graz. Machine Learning (ML) and especially reinforcement learning (RL) techniques in the field of rock mechanics/tunnelling and related interaction with machinery, besides research covering the anisotropic rock behavior, will be at the center of our future cooperation. Prof. Raul Fuentes' institute is a co-partner in our COST application to the EU, which is about finding and connecting interested research partners within the use of ML/RL in geotechnics. At the end of this x-change network an EU horizon application is intended. Furthermore, a regular exchange in teaching and laboratory research activities is planned.

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Recent RMT Guests II

G. Valentin & M. Keuschnig

On November 18th, 2021, we had the pleasure of welcoming Mag. Gerald Valentin and Dr. Markus Keuschnig MSc. at Graz University of Technology (TU Graz). Mr Valentin is a geologist of the province of Salzburg, and Mr Keuschnig is chief technical and digital officer of the GC group and founder and managing director of the GEORESEARCH Forschungsgesellschaft mbH.

Figure 2. Corner reflector: to monitor ground motions precisely in areas where no other artificial or natural reflectors are available. © GEORESEARCH Forschungsgesellschaft mbH

They came to Graz to give a guest lecture about the potential of satellite based InSAR and its use for the detection of mass movements.

The lecture started with the theoretical background of this technology, which gets used more frequently throughout many sciences. Mr Keuschnig presented measurement principles of and algorithms for InSAR, and some pros, cons, and specs one should know within a short time, but in a very clear and comprehensible way. SAR satellites and orbit, the line of sight, the off-nadir angle, the properties of signals, accuracy and data quality have been topics he addressed, just to name a few. Both, Mr Valentin and Mr Keuschnig then showed the audience results from several applications in the field, e.g., the variation of the groundwater table related to the subsidence and uplift of the historic centre of the city of Salzburg, the monitoring of mass movements in the valley of Gastein or the monitoring of the Tauern motorway.

21 people registered to take part on site. Over 60 people registered for the live-streaming. After the insightful lecture, many of the participants took the chance and asked questions. Some of them relating to details of the presentations, others to challenges at the participant's projects. The Q&A session almost took longer than the lecture itself. Anyway, the lecturers met the questions successfully.

The guest lecture was used as a kick-off for a future collaboration between the lecturer's institutions and TU Graz relating to monitoring with InSAR.

Because the topic is hot, but questions and concerns relating to how to and when to use InSAR still exist, the lecturers promised to provide introductions and seminars to interested clients in the future.

See you. [with satellites]

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Teaching Highlights I

Field Excursion Rock Mechanics

In September this year the annual lecture “Field Excursion Rock Mechanics” took place. Thereby, interested students were given the opportunity to visit construction sites in person and obtain valuable impressions from practice. This year, our first stop was at the "Zentrum am Berg“ in Eisenerz, Styria. On site we were guided around the 1:1 scale research center and got impressions of the many exciting research projects and courses that are held in this unique facility.

On the second day, we visited the construction lot 3.1 Grautschenhof which is part of the Semmering Base Tunnel. After an introduction to the whole project itself, we went underground. We were explained the challenges of tunnel construction in fault zones and how they are dealt with in practice. Many of the students had never been on a construction site of this size before, which aroused great amazement and enthusiasm for tunnel construction in them.

On the last and third day, we went to Vienna. Here we were privileged to visit the construction work for the future final destination of the extension of the U2 subway line. In addition to giving us an insight to the many special civil engineering measures taken, our guides showed us how great the demands on logistics are in urban tunnel construction. Compared to the construction sites of deep base tunnels, it was quite different, but certainly not less interesting!

During this three-day excursion the students were able to gain impressions from large 1:1 laboratories, respectively innovation centers, construction sites of deep lying tunnels and urban tunnel construction.

A big “Thank you!” to all who made this excursion possible.

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Teaching Highlights II

NATM University Program – Module 2 and outlook for module 3

Similar to the first module of the NATM University Course, the second module had to be held completely online due to the COVID situation. However, with the experience we already gained from spring this year, the second module could also be held successfully. A variety of teaching contents were covered within this module, including the topics of “BIM in Tunnelling” or TBM and road header excavations. Further, the participants could work on their first exemplary tunnelling project applying the concepts of the “ÖGG Guideline for the Geotechnical Design of Underground Structures with Conventional Excavation”. With the help of the motivated participants from Colombia to Singapore, another showcase of successful digital teaching was established.

At the moment we are preparing for the upcoming module 3, which is taking place in April 2022. Due to the cancellation of all excursions intended for module 1 and module 2, a two-week excursion is planned, which will lead us from the west of Austria via Germany to Vienna and back to Graz. In the course of the third module, the participants will be able to visit all tunnel construction relevant sites live in order to gain a better understanding of the concepts applied in tunnelling.

We are looking forward to an exciting next module!

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Site Reports

Construction site visit Nykirke - Barkåker
IC rail project (Norway)

In late August two members of our Institute's Machine Learning in Geotechnics (MLGT) research group, Georg Erharter and Paul Unterlaß, completed a two weeks research stay at the Norwegian Geotechnical Institute (NGI) in Oslo. The stay was filled with hackathon like events and intensive research exchanges pushing the joint research in the field of machine learning in geotechnics.

In the course of the stay we were given the opportunity for a site visit of the Nykirke - Barkåker Intercity rail tunnelling project. The modernisation of the Vestfold Line, significantly reducing travel times to Oslo, will in future provide a better railway service to the inhabitants of the Vestfold/Grenland area. As part of the overall modernisation of the line, several tunnels are to be excavated and a number of major road cuts have to be made. As being well known, different countries have different approaches and follow different philosophies, also in tunnelling. For us, being used to the application of the New Austrian Tunnelling Method (NATM), it was particularly interesting to get first-hand insides into the Norwegian way of tunnelling and the Q-system in application.

Figure: Blasting lengths of up to several meters require special equipment for scaling works.

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Rigorosum Georg Erharter

At the end of every doctoral program there is the “Rigorosum” which is a final presentation and defense of a doctoral thesis. The Rigorosum consists of two parts where the doctoral student first has 30 minutes time to present his / her thesis and then there is an examination of one hour by a commission of three professors.

On September 30th, the time has come for Georg Erharter to finish his doctoral thesis and defend it in front of the commission that consisted of Univ. Prof. Thomas Marcher (main examiner and supervisor), Univ. Prof. Raul Fuentes (second examiner, see article on page 8) and Assoc. Prof. Franz Tschuchnigg (third examiner / chair of commission). The thesis has the title “From Rockmass to Information – the Applicability of Machine Learning for Geotechnics” and is a cumulative dissertation that consists of four main publications in international, high-ranking journals that cover the topics: unsupervised learning based rockmass classification, supervised learning based prediction of TBM data, supervised learning based classification of CPT data and reinforcement learning based tunnel process optimization.

The Rigorsum of Georg Erharter was a success, and he finished his doctoral studies with distinction as the first doctoral student of Prof. Thomas Marcher. After his doctoral studies Georg Erharter will stay part of the RMT-team and continue his research and teaching activities as a PostDoctoral researcher.

Figure: Thomas Marcher, Franz Tschuchnigg, Georg Erharter and Raul Fuentes (from left to right) after the Rigorosum

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Institute Outing (Institutsausflug)

On the 8th of September our institute's half-yearly outing took place. We started into the day with a rich breakfast at the renowned hotel Weitzer in the city center of Graz. The subsequent item on the program was a visit to the Jochen Rindt exhibition at the Graz Museum which was dedicated to the former world-famous and exceptional Austrian racing driver who grew up in Graz and tragically died in 1970 in Monza during a practice for the Formula One Italian Grand Prix.

As the weather conditions didn't allow for an ensuing visit of an outdoor Go-kart facility, the plans were shifted in favor of an activity that was no less competitive – Bowling. Surprisingly, some of the institute's members let it look like they were never doing anything else and therefore the number of strikes (knocking down of all pins on the first ball roll) that were encountered rose to a very high number. The lucky overall winner, if luck really played a role in this fiercely contested competition, was none other than our ambitious colleague Thomas Geisler – "Congratulations Tom, well done".

The relaxed day away from everyday university life came to an end with a dinner at the restaurant "Brot und Spiele" located in the up and coming city district Lend.

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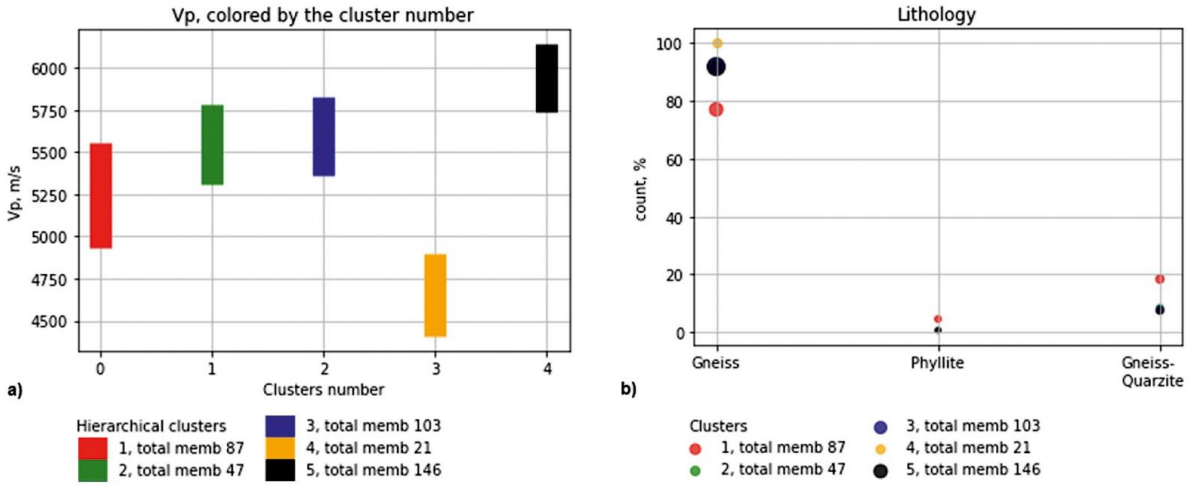
Publications & Presentations I

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

Towards the integration of smart techniques for tunnel seismic applications
Dickmann, T., Hecht-Méndez, J., Krüger, D., Sapronova, A., Unterlaß, P.J. and Marcher, T.
Published on 01 October 2021 in Geomechanics and Tunnelling Volume 14, Issue 5, p. 609-615

Applications of seismic measurements for the prediction of hazard zones are applied practice in many tunnel drives in rock mass today. Next to a large exploration range and accurate localisation of discontinuities, seismic data provide attributes for a comprehensive characterisation of the ground conditions. A good synchronisation of all technical components is required to obtain optimum data quality and quantity while the tunnel excavation is not obstructed thereby. Firstly, the signal source must feed as much energy as possible into the rock in a very short time. Secondly, continuity of the signal generation with constant quality and its precise timing by means of wireless data transmission also ensure a reliable measurement process. Artificial intelligence is used to determine the quality of the recorded data already in the tunnel and feedback is given to the user keeping the data quality high. From the tunnel site, recorded raw data can be transferred to a cloud, from where an authorised processor collects them, wherever in the world. An immediately started data processing delivers a result within an hour that includes a geological forecast of up to 150 m of heading, depending on the rock mass condition. In addition to data quality, the quality of the results is crucial. Therefore, techniques are currently under development using machine learning to correlate and analyse seismic attributes with geological properties. This should lead to a more objective evaluation of the geological forecast in the future.



Unsupervised clustering of feature sets consisting of measured P- and S-wave velocities, the calculated density, the Poisson's ratio and the dynamic Young's, bulk and shear modulus. a) Range of the P-wave velocities for implicitly detected clusters. b) Distribution of lithology types in detected clusters

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Publications & Presentations II

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

Conference presentations on the topic of tunnel seismic prediction using Machine Learning
Sapronova, A., Unterlaß, P.J. , Hecht-Méndez, J., Dickmann, T. and Marcher, T.

The results from a new work, where data analysis was used to predict the conditions ahead of the tunnel face, were presented in two conferences: MRLA - MACHINE LEARNING & RISK ASSESSMENT IN GEOENGINEERING, Joint International Symposium of Two Events 3ISMLG & TCWW (hold in Wroclaw, Poland, October 25 - 27) and EAGE - 27th Near Surface Geoscience 21 (hold in Bourdeaux, France, 27 August - 2 September).

This work is a result of a collaboration between RMT and Amberg Technologies AG. In this project, the tunnel seismic prediction (TSP) system collects seismic signals reflected due to changes in the elastic rock mass associated with discontinuities. The unsupervised machine learning methods employed to cluster the data from TSP provide an improvement in the identification of rock mass class and lithology type. Discovered clusters that contain over 90% of a single type of rock mass and lithology are used to remove subjective labeling from the dataset. Improved labels are fed into a supervised machine learning model that predicts the rock mass class from TSP data. The proposed methodology highlights a pathway towards an improved interpretation of geological conditions ahead of the tunnel face.

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A new parameter for TBM data analysis based on the experience of the Brenner Base Tunnel excavation
Heikal, G., Erharter, G.H. and Marcher, T.
IOP Conference Series: Earth and Environmental Science (Open Access)

Tunnel boring machine (TBM) operational data can be seen as a function of three main influences: the machinery of the TBM itself, the way the TBM is operated, and the excavated rock mass. Whereas the processing of TBM data must be done by computer-aided methods, the interpretation is typically done visually and is highly dependent on the user's prior experience. One way is to inspect the raw data itself, and another is to inspect computed parameters. Either way, the goal is to find distinctive patterns that indicate changes in the rock mass conditions, and therefore it is crucial to find parameters that bear as much information as possible. The goal of this paper is to introduce the new parameter "theoretical advance force" ($F_{N,theo}$) that was developed in the course of systematic analysis of TBM operational data from the exploratory tunnel Ahrental Pfons (part of the Brenner Base tunnel). $F_{N,theo}$ is back-calculated from the measured cutterhead torque and penetration. The theoretical advance force shows very promising results with the data at hand, yielding more pronounced and well-defined patterns that correlate better with the encountered rock mass conditions than several other common parameters.

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Faces

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

Andreas Gaich

I've been employed at the Institute of Rock Mechanics and Tunnelling as a research fellow from 1997-2000 within the scope of the SITU project. Our goal was to enhance the mapping work of geologists during conventional tunnelling by use of digital imagery and photogrammetry that led to 3D models. Dedicated software components assessed the 3D models and transferred the mapping procedure onto a computer. This approach led to the foundation of 3GSM GmbH in 2002 and our first product. **ShapeMetriX** was applied at several tunnelling projects in a regular manner. Wulf Schubert suggested then to extend this principle to mechanized tunnelling where we did our first trials in 2005. Today that system works by automatic 3D model generation from video data and controlling the camera via smartphone.3GSM expanded its applications also to the mining industry with focus on rock mass characterization, blast engineering, and general surveying tasks. The **BlastMetriX** system defined the industry standard for photogrammetry-based bench face profiling – a task that is required in quarry blasting. Now, the developments found to each other providing a synthesis of the single components and driving the digitization of the quarry industry. 3GSM's software products have been shipped to 50 countries on all continents with their clients ranging from smallest engineering consultancies to the largest mining enterprises in the world.

3GSM – Simply Measure!

Maryam Abdulbaki

My first experience with rock mechanics started rather late. I never took any courses related to rock engineering during my bachelor's program and had no experience working in this field of engineering when I was a junior engineer. Rock mechanics and tunnelling is not a common subject in my country of origin, Nigeria, or in the United Arab Emirates where I obtained my bachelor's degree in civil engineering. My initial intention, when starting my master's program in Geotechnical and Hydraulic Engineering at Graz University of Technology, was to focus more on soil mechanics, as this was my area of focus during my bachelor thesis. My interests in rock engineering started when I first took the course Rock Mechanics and Tunnelling followed by the Advanced Rock Mechanics and Tunnelling lectures. During the summer I was fortunate to visit some construction sites like the Semmering Base Tunnel, the Vienna Metro or the "Zentrum am Berg", and I was completely fascinated. I like the flexibility within this field of geotechnical engineering with the constant effort to employ new innovations. I am currently investigating the concept of transverse isotropy in the course of my master's project, which is the basis in rock engineering to deal with the stiffness anisotropy that many rocks naturally display. I am already looking forward to extend my research also across other aspects of rock mechanics.

Diary of Events

Barbarafeier - CANCELLED
Graz, Austria (2021/11/26)

Due to the current COVID situation we were unfortunately forced to CANCEL the Barbara Celebration 2021 of the Institute of Rock Mechanics and Tunnelling at TU Graz. We thank all companies who have been willing to support our event. We hope to see you all again at the next year's celebration.

2nd ATC²-Symposium 2021 – Changed to ONLINE only
Leoben, Austria (2021/12/02)

Symposium by the Austrian platform ATC² (Austrian Tunnel Competence Center), a collaboration of Graz University of Technology and Montanuniversität Leoben. The aim of the symposium is to transfer innovative ideas and know-how in tunnelling. In English. You can attend the event online. The program and further information on the symposium can be found on the ATC² website
http://austrian-tunnel-competence-center.at

Smart technologies for geological forecasts using in-tunnel seismics during tunnelling
Graz, Austria (2022/01/27, 5:15 p.m. CET)

© Thomas Dickmann, Amberg Technologies AG

Lecture by the Head of the Business Unit Geophysics of Amberg Technologies AG, Dr. Thomas Dickmann. The lecture will be in English and will take place in the lecture room HS L (Lessingstraße 25/1, 8010 Graz) if the COVID situation allows for it to be held in presence. In any case, there will be a live-streaming. Registration via email addressed to tunnel@tugraz.at. If you register, please comment whether you will attend the event on site or online.

The Long Night of Research at TU Graz
Graz, Austria (2022/05/20)

Researchers all around Austria will allow a unique look behind the scenes and bring their research to life for one night. Our team will show some exciting tests in the rock mechanics laboratory. Registration via email addressed to tunnel@tugraz.at.
[additional information]

EURO:TUN 2021 goes SFB 873 & EURO:TUN 2022
Bochum, Germany (2022/06/22-24)

Due to the pandemic situation, EURO:TUN 21 was shifted to 22.-24.06.2022. The EURO:TUN conference focusing on Computational Methods and Information Models in Tunneling will take place in the Conference Centre of the Ruhr University Bochum (RUB). The conference will be combined with a workshop on Interactive Modeling in Mechanized Tunneling. More information on the conference can be found here: http://eurotun2021.rub.de

36. Christian Veder Kolloquium 2022
(2022/04/21-22)

Annual conference hosted by the Institute of Soil Mechanics, Foundation Engineering and Computational Geotechnics with the special topic of "Besondere Herausforderungen in Planung und Ausführung beim Bauen in weichen Böden". Conference is held in German without simultaneous translation. For further information see:
https://www.tugraz.at/institute/ibg/events/christian-veder-kolloquium/

Mini-Symposium "Rockfall Risk"
Schladming, Austria, November 2022

Exact date and contents of the Mini-Symposium to be announced on our institute's homepage.

Have a look at our Master‘s Theses I

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


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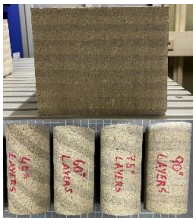
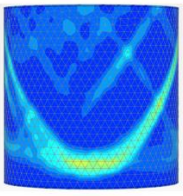
- **Mission to the Mars (supervisors: G. Erharter, G. Grömer (OeWF))**

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



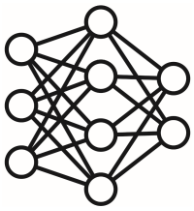
- **Artificial rock samples / Anisotropy (supervisor: M. Winkler)**

Rock is a complicated material, for example it is very often anisotropic making its’ deformational and strength characteristics dependent on the loading direction. To learn more about this phenomenon, numerical and experimental studies are carried out. Modern sand 3D-printing techniques aid in manufacturing of artificial rock samples which allow for the investigation of anisotropy without the influence of sample inhomogeneities.



- **Hard soil soft rock**

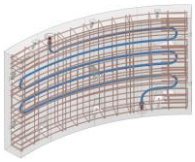
Have you ever wondered what the difference between a stone and soil is? This question is more difficult to answer than expected and is the focus of the research field Hard Soil-Soft Rock (HSSR). Therefore, many engineering problems in geotechnics can be linked to excavations in hard soils or soft rocks.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



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

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

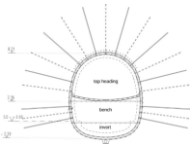
Have a look at our Master‘s Theses II



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

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

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



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

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

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

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

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

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

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

In addition to these main research areas, further master theses are supervised, which can be found on the website. [overview of master's theses]

Cooperation

… please contact us in case we forgot you here