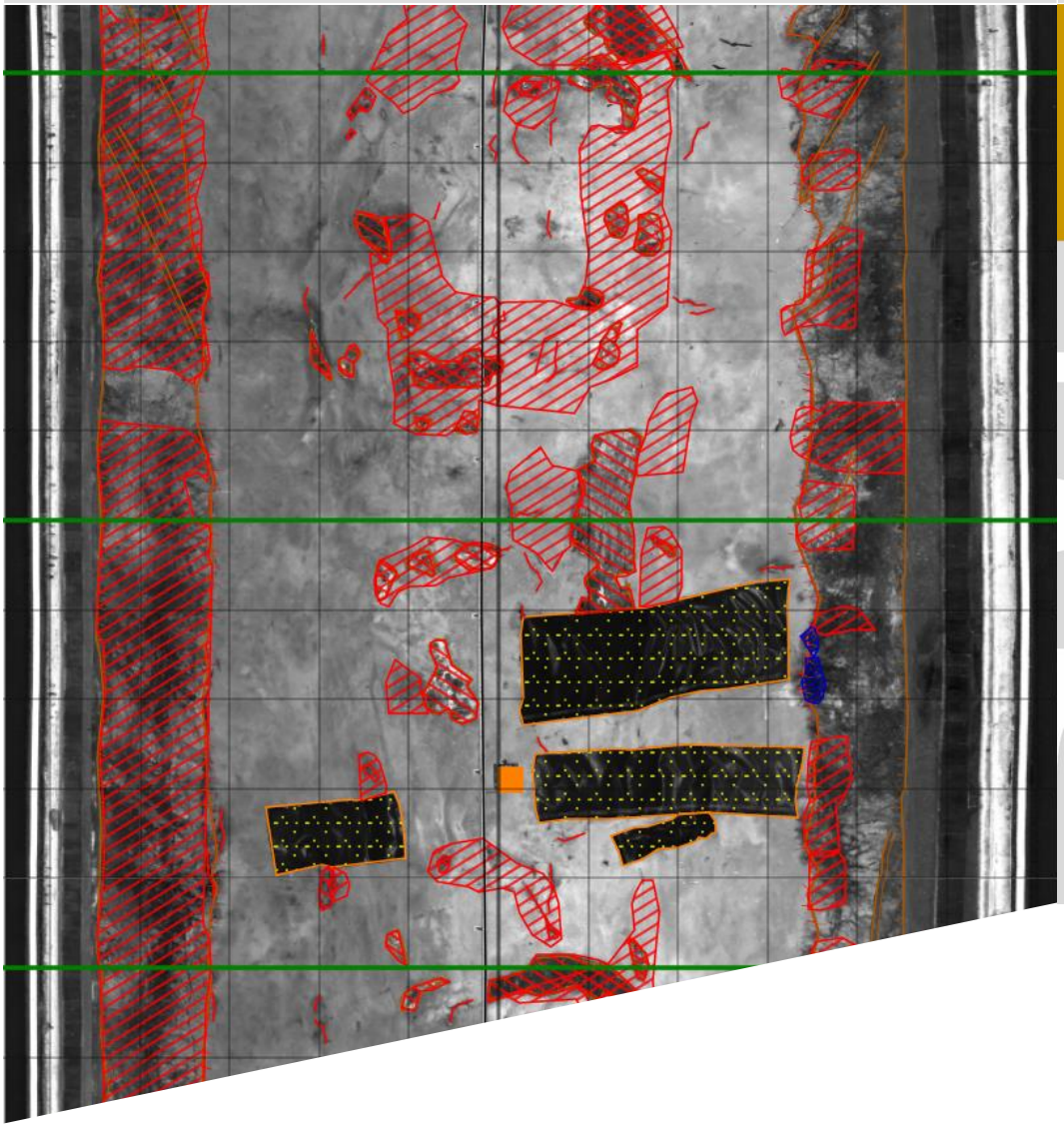
# ROCK REPORT

Mechanics & Tunnelling

Quarterly Newsletter of the Institute of Rock Mechanics and Tunnelling

**03** Volume 2
August 2021

RMT



NAWI Graz
GEOZENTRUM

TU Graz
Graz University of Technology

MLGT
Machine Learning in Geotechnics

# Content



**Marcher's Column**

Good news: TU Graz has just announced "*As Much Presence as Possible*" for the upcoming semester! Let's hope that students will meet on our campus again.

I am looking forward to the "new normality". Meeting up and exchanging ideas in an informal and spontaneous way again is an elixir of life at the university. But not only this: teams working together again in the physical offices, face-to-face discussions and exchanges of opinions, meetings, lunches together, after-work beers.... Finally, that's back!

In this Rock Report, we focus on several aspects: first, I am proud to welcome an expert in data science and AI to our RMT team. Alla Sapronova started her position as tenure track professor last month. As described in previous issues of the Rock Report, ML/AI and data science are becoming an important tool in rock mechanics and tunnelling. I am looking forward to our next promising research topics in this regard.

In 2019, Alexander Kluckner and I visited several Asian countries to share research and invigorate collaboration: Japan, Singapore, Indonesia and Malaysia. With UNITEN Malaysia, we now have the honour of working on risk assessment of existing waterways of hydropower plants. We have started with workshops to share know-how. A great collaboration!

Glück Auf and stay healthy!

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**Title Picture**:
Tunnel inspection scan with overlayed damage mappings on the Amberg Inpection Cloud


09. August 2021 – published
Manuel B. Winkler – editor in chief
tunnel@tugraz.at – contact

# Project Focus I

## First step towards a promising cooperation between UNITEN and TU Graz & partners


*Figure 1. Group photo at the Institute of Energy Infrastructure (UNITEN) in Kajang, Malaysia, on December 11th, 2019. Copyright owner of the image is Ms Assoc. Prof. Ir. Dr. Rini Asnida Binti Abdullah from Universiti Teknologi Malaysia (UTM).*

End of 2019, Prof. Thomas Marcher and Alexander Kluckner had the opportunity to pay Universiti Tenaga Nasional (UNITEN), a private university in Selangor, Malaysia, a visit (Figure 1). UNITEN is an energy-focused university with five colleges and five research institutes. One of it is the Institute of Energy Infrastructure (IEI) led by Ms Assoc. Prof. Dr Rohayu Che Omar (Figure 2, left). A collaboration agreement between UNITEN/IEI and the Institute of Rock Mechanics and Tunnelling (RMT) exists already since 2016. Thus, we took the chance and refreshed the relationship by a visit and look forward to a future collaboration.

Approximately one year later, the time had come. UNITEN accomplished to get a new project granted which deals with the quantitative risk assessment of existing waterways of hydroelectric power plants. Project leader at UNITEN is Ms Intan Nor Zuliana Binti Baharuddin (Figure 2, left). And - the best of it - UNITEN wanted to have us on board.

In a first step, RMT has been entrusted to organize two workshops via videoconference showing the European or western way of maintaining such structures and how to assess their integrity.

*Figure 2. Ms Rohayu Che Omar and Ms Intan Nor Zuliana Bini Baharuddin from UNITEN (left). Mr Kluckner from TU Graz (right). Copyright owner of the images are the individual persons.*

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# Project Focus II

The first workshop took place beginning of July this year. And it was a full success. The workshop extended over two days, starting at 8 a.m. CET and ending at 5 p.m. CET. Because of the time shift, in Malaysia the workshop started at 2 p.m. MYT and ended at 11 p.m.! Kind of late for the Malaysian engineers and researchers. Thank you for holding out for so long. Anyway, the number of participants ranged between 14 and 28. Business was running alongside and Muslim prayer times were appreciated, too. The participants have been experienced researchers, engineers, and project managers from UNITEN and from Tenaga Nasional Berhad (TNB). TNB is the multi-national energy company owning UNITEN. For the workshop, RMT could bring several experts together, giving excellent lectures. That had been (see Figure 3 from top left to bottom right)

- Mr Wolfgang RICHTER and Mr Edwin STAUDACHER from the Institute of Hydraulic Engineering and Water Resources Management (Homepage), Graz University of Technology,
- Mr Matthias REBHAN from the Institute of Soil Mechanics, Foundation Engineering and Computational Geotechnics (Homepage), Graz University of Technology, supported by Mr Michael MAYER and Mr Dirk SCHLICKE from the Institute of Structural Concrete (Homepage), Graz University of Technology,
- Ms Martina PUGLIA from Amberg Engineering AG (Homepage),
- Mr Michael BURI from Amberg Technologies AG (Homepage), and
- Mr Thomas MARCHER from the Institute of Rock Mechanics and Tunnelling (Homepage), Graz University of Technology.

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*Figure 3. Lecturers and supporters at the first workshop. From top left to bottom right: Mr Richter, Mr Staudacher, Mr Rebhan, Mr Mayer, Mr Schlicke, Ms Puglia, Mr Buri, Mr Marcher. Copyright owner of the images are the individual persons except: Mr Rebhan (© simon.jimenez.at), Mr Marcher (© Lunghammer/TU Graz).*

On the first day, Prof. Marcher started the session and talked about what is important when dealing with waterways in rock underground. He focused on the key aspects of ground characterization and classification, on common hazards in tunnelling and methods to identify them in time, and on long-term effects at underground constructions with special focus on waterways. Mr Staudacher continued and introduced some approaches for the surveillance and inspection of power plants with large dams. Dr Richter held the last lecture on that day where he first summarized philosophies to design headrace systems which have been successfully constructed and operated for a very long time in history. He was highlighting milestones of around 120 years of pressure tunnel design development in Austria. He then, for example, illustrated in which case a tunnel section can remain unlined but also in which case he strongly recommends the installation of a permanent lining. He also highlighted the Norwegian pressure tunnel design philosophy and the importance of sediment traps and other features for economical design and sustainable operation.

# Project Focus III

He kept pointing out that the design of pressure tunnels, especially in connection with pumped-storage hydropower, is a key technology to tackle climate change with the integration of renewable energy with its flexible, vast and multipurpose storage opportunities.

The next day Dr Rebhan had the honour to open the session. He shared his experience in the integrity assessment of reinforced concrete structures that he has gained in many projects in the past years. Next to typical damages, hazards, and factors triggering them, he also showed common monitoring and testing methods. Then, the experts from Switzerland entered the online stage. The first and only woman of the team of lecturers, Ms Puglia, impressively showed the participants how inspection can be done successfully. She broke the complex topic down to a reasonable sequence of single important steps and even took us to an inspection of a Swiss tunnel using the Amberg Inspection Cloud (see cover image) – a mapping tool that allows to overlay scan images with the mapping of the damages. Mr Buri followed her with his lecture on recent technologies to improve site inspections. He showed the capabilities of the tools they establish, such as the Amberg Inspection Cloud, and the benefits of having data and information in a digital form to be processed in the office. Although Dr Richter was the last lecturer on that day, too, he could attract the attention by the participants. He continued highlighting the importance of considering changes in the pressure situation during operation and also during dewatering for inspection. Dr Richter finished the session with lessons learned from several power plant projects around the world.

The lecturers showed insightful images, sketches and videos and tried to sensitize the participants regarding how-to and how-not-to. A Q&A session followed each lecture unit at which all parties involved discussed relevant, practical problems and learned from the experience and knowledge of others.

On behalf of TU Graz and RMT, the moderator, Mr Alexander Kluckner (Figure 2, right), thanks all lecturers for their contribution and the motivating cooperation during the preparation of the workshop. He also thanks UNITEN and TNB for this unique opportunity and the participants for attending the workshop and their interest in the lectures.

See you soon at the next workshop!

Stay safe and keep rocking.

Alexander Kluckner

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# Project Focus IV

Some impressions from the workshop …

**Ms Martina Puglia**

*We had a first online meeting for the preparation of the training, and after that, all contact was via email. The preparation of the training went very well - so well, that even without really talking in detail about the content of each presentation, everything fit. It was nice to see how the different aspects from the characteristics of the materials to the environment of the structures play a role in the inspection of a structure, whether it is a tunnel, a retaining wall or a waterway.*
*A video conference has as many advantages as disadvantages - no jet leg is a nice side effect, but we miss the opportunity of seeing the reactions of the participants. Nevertheless, many good questions have been asked and we were able to discuss interesting topics together. There are many issues that still need research and new answers.*

**Mr Edwin Staudacher**

*The workshop has been a very good opportunity to exchange state of the art insights between several civil engineering disciplines that meet in hydraulic engineering between TNB, Amberg Engineering, Amberg Technologies and TU Graz. Especially, I enjoyed the lively discussions in addition to the lectures between all participating parties. May this first workshop be the offspring for an interesting collaboration in the future.*

**Mr Wolfgang Richter**

*Even during a time of worldwide restrictions, it was possible to hold this very constructive workshop from two parts of the world with 6 hours time shift and a great endurance until 11 p.m. in South East Asia. I appreciated the high interest in the experiences of pressure tunnel design in Austria and the fruitful discussion with the situation of hydropower plants in Malaysia. I am looking very forward to further exchange on this important technical field for resilient energy systems.*

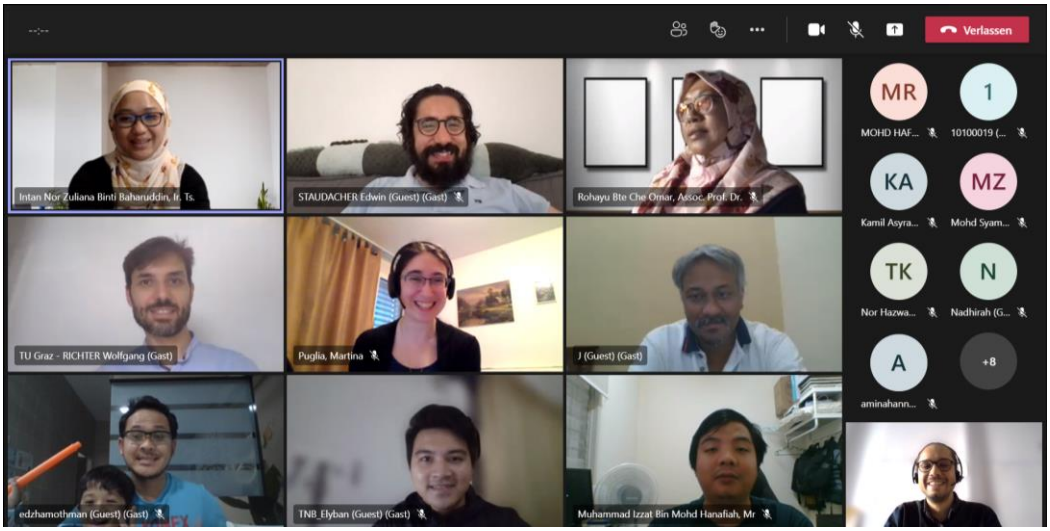


*Figure 4. Online group photo after the session on day 2.*

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# Research Focus I

## Data science perspectives – an introduction to assistant professor „Alla Sapranova”

Dear colleagues from science and industry,

My name is Alla Sapranova. I am a physicist by education, a curious person by nature and I have been working with data science and machine learning for over 13 years.

I graduated from Moscow State University, Russia, with a Ph.D. in physics and mathematics in 2004. In the following two years, I served as an adjunct professor at the Department of Physics at the Boise State University, Idaho, USA. In 2008, I finished the postdoctoral program at the University of Bergen, Norway. My work focused on computational physics. Namely, I was modelling the response and dynamics of complex multiphase systems. That time I learned about data analysis and in 2009 I started my journey in data science and artificial intelligence as a senior researcher at the Bergen Center for Computational Science. In 2014, I joined the Big Data Analysis Center at the University of Bergen as the head of data science. My responsibility ranged from project management and programming for data science to team-building and networking. From 2012 - 2016 I served as an external sensor for the Department of Physics and Technology at the University of Bergen and the Centre of Expertise in Forecasting at Nelson Mandela University, Port Elisabeth, South Africa. In 2019, I mainly shifted my expertise towards industrial applications and became a lead data scientist for the StormGeo company in Bergen, Norway. There, I worked with data analyses and forecasting to deliver machine learning solutions within digitalization, data-driven decision support, and risk analysis. By that time, I received five personal grants from the Norwegian state and industry partners for R&D within the fields of machine learning and data science. I have expertise in data science, machine learning, big data, and programming. As a data scientist, I completed projects for various industries and public sectors, ranging from medical hospitals over fisheries to oil drilling and electrical grid safety monitoring. In 2021, I was short-listed in "Nordic Top 100 in Data, Analytics & AI" according to the global media company Hyperight broadcasting news in data utilization and innovation.

Since July 2021, I am now a part of the RMT team and serve TU Graz as an Assistant Professor, focusing on data science applications for geotechnical engineering.

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# Research Focus II

## Data science perspectives – How algorithms will help us to handle geotechnical data

The growing volume of data available in geotechnical engineering provides unprecedented opportunities to apply advanced data analysis techniques. It opens a possibility for data-driven modelling for prediction and decision support in geoscience.

Of course, some of the techniques have already been used in traditional geotechnical engineering. For example, regression analysis is one of the oldest methods of a machine learning algorithm in geotechnics, and it is commonly applied to correlate different properties. However, the recent evolution of the data science approaches can provide new methods leading to a dramatic improvement in the interpretations and risk assessment.

Due to the nature of the operating environment, experts in the fields of geotechnical engineering and related geosciences have to deal with a significant number of uncertainties. And engineering judgment, while still being one of the widely adopted solutions to combat uncertainty, is highly subjective and relies on the expertise of a person. Data science and machine learning are ready to provide tools and methods for automatic unbiased information extraction via data-driven modelling to eliminate the subjectivity of the interpretations.

The sparsity of the data in geoscience is the main constraint for data-driven modelling. For example, the preprocessing (denoising) and application of the majority of the analytical methods, including unsupervised methods, are negatively affected by the data sparsity. The sparse datasets can contain either irrelevant or erroneous inputs. This fact calls for new ways for data preprocessing and inputs pruning to ensure the successful application of machine learning predictive techniques.

Developing a methodology for automatic preprocessing of the sparse geotechnical data would allow integration and analysis of the complex geotechnical data. Consequently, this will help to build robust data-driven models, e.g., to predict the geological conditions ahead of the tunnel face.

The application of the data science and machine learning methods would help to eliminate the subjective perceptions in prediction, aid to improve the accuracy of the geological conditions forecast and can become a base for building risk management and decision support systems for geotechnical applications.

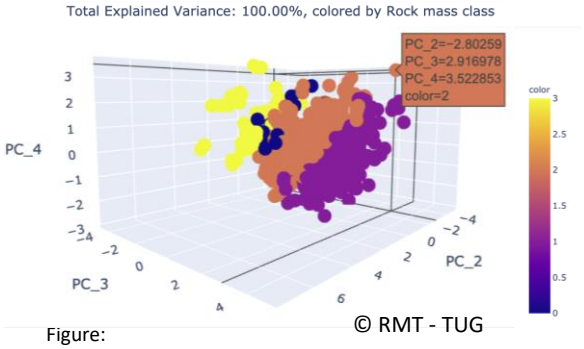


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Figure:
High-dimensional data from tunneling survey for hazard zones' recognition mapped to the low-dimensional space with principal component (PC) analysis and clustered according to the rock mass types (color-coded).

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# Recent RMT Guests

## U. Burger

On June 10th this year, Mag. rer. nat. MSc Ulrich Burger visited our institute online and gave an excellent public lecture about "Hydrogeological (risk-) analysis for tunnelling in quartz phyllite regions". Mr Burger is a senior hydrogeologist at the Brenner Base Tunnel project. In the lecture he not only shared his experience and knowledge he accumulated since 2004 when he started his work for the GALLERIA DI BASE DEL BRENNERO–BRENNER BASISTUNNEL BBT SE but also from his work at civil engineering offices and as associate lecturer at the University of Innsbruck.

The collaboration between Mr Burger and the institute started in 2019 when the idea was (re-) born to investigate the potential at the Brenner Base Tunnel project for energy and heat extraction from the ground and the water (cf. article relating to the project "ThermoCluster" in the third issue of the last year's Rock Report series on p. 10: LINK). Ever since, the collaboration with him (and with other experts from BBT SE) is extremely valuable for the entire team involved in this project (University of Natural Resources and Life Sciences in Vienna , Geological Survey of Austria, AIT Austrian Institute of Technology GmbH, Innsbrucker Kommunalbetriebe AG).

Prof. Thomas Marcher, head of our institute, knows Mr Burger already for decades and appreciates the friendship with him and his expertise. Because of the successful collaboration, Prof. Marcher thought it is now a good time to invite Mr Burger to hold a guest lecture. This was a success too. Mr Burger presented an interesting but sometimes complex topic in a way so that the audience could follow the explanations easily. Over 30 participants from Austria, Germany, and Italy attended the lecture and the subsequent discussion. On behalf of the institute, the author thanks Mr Burger for his talk and the participants for being interested and for their questions during the Q&A session.

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# Teaching Highlights I

## Applied Data Analysis 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.


Generated with Mathematica 12.2 with data from Wikipedia

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# Teaching Highlights II

## NATM University Program – Module 1

Already for the 6th time, the NATM course, which is held jointly by the Graz University of Technology and the Montan University Leoben, has started.

However, with a COVID-19 related adjustment: For the first time, the course was held online, but this did not dampen the enthusiasm and interest from the participants. On the contrary, the participants got the chance to listen to the lecturers from industry and universities from home and to gain new knowledge.

Participants from 9 different nations, scattered all over the globe and in different time zones, attended the course. A time window was carefully chosen in which each participant had the opportunity to take part in the course. So while the colleagues from Colombia enjoyed their breakfast coffee, the colleagues from Singapore already had their dinner.

In summary, the feedback for the course was exceedingly positive and we are looking forward to a great next semester, once again online, before we hopefully all get to know each other in person in Austria!


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# Site Reports

## Mapping at the Wasserradkopf

In the course of the INTERREG project SedInOut, a debris fan near the famous and highest mountain of Austria, the Großglockner, was surveyed last September together with the geological survey of Carinthia and the company 3GSM GmbH. This debris fan on the flank of the Wasserradkopf is being investigated with regard to its remobilization potential and thus the risk it poses for generating alpine waterways and causing mudflow events.

In the first data acquisition campaign, the debris fan was surveyed with a drone and photos were taken for photogrammetric analysis of the grain sizes. These results were recently validated at selected locations in the debris field. For this purpose, rasters were measured at designated locations and the grain sizes and rounding degrees were evaluated manually along these rasters and compared with the results from the digital photogrammetric analysis. The gathered results will finally serve as an input for subsequent numerical analyses.

An exciting project with a lot of great field mapping days in the Austrian mountains!



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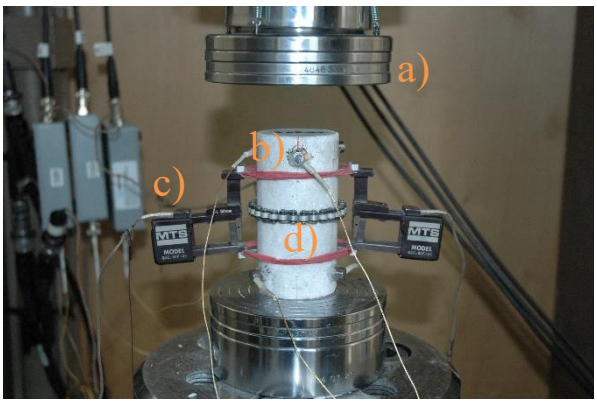
# Publications & Presentations

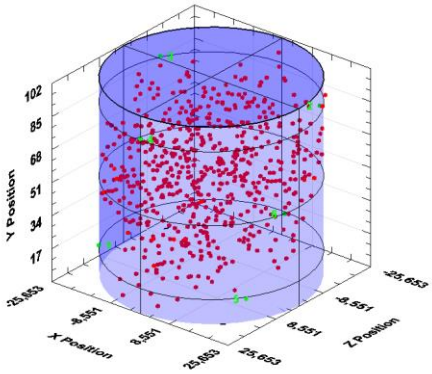
All publications of the institute are listed chronologically on our homepage. Selected papers and presentations are presented here.

**Influence of rock's structure at grain-scale on rockburst proneness**
*Klammer, A..; Gottsbacher, L..; Biermann, J.; Zobl, F; Marchallinger, R.; Hofmann, P.; Marcher, T.; Schubert, W. (Accepted at EUROCK 2021, Torino)*

As projects advance to deeper areas, rockbursts occur more frequently. This failure mode is particularly problematic, as the rock mass fails abruptly, releasing high amounts of energy, endangering the life of workers and damaging equipment. The hazard mode is highly influenced by the grain-level structure of the rock. The authors demonstrate this by comparing the grain-level structure of different rocks to their failure mechanism.

For this an extensive laboratory program was performed, including uniaxial compression tests (incl. post-failure tests to evaluate the failure energy), acoustic emission testing (to monitor the cracking activity) and Object Based Image Analysis (OBIA) to analyze rock's structure at grain scale using thin sections taken before and after the compression test. The results allow a better understanding of the underlying mechanism and emphasize the usefulness of petrographic information within rockburst risk analysis.




Testing set up ( a = loading frame; b = AE sensors; c = axial strain gage; d = circumferential strain gage) and 3D Location of AE events (in this case a very uniform distribution)

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**Lecture at the Bergbaumuseum Steinhaus**
*Marcher, T.*

Prof. Marcher gave an insight into the fascinating world of rock mechanics in the area of interaction between geology and civil engineering at his original home "Ahrntal" (South Tyrol, Italy). The lecture "Rock mechanics - pure stresses!" was organized by the "Regional Museum of Mining" on July 14th 2021 and held at the Steinhaus /Ahrntal site. Interested parties can access the lecture on the museum's YouTube channel (in German). In addition, an interview was printed in the local district newspaper (in German).

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# Faces

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

**Karl Grossauer**

I studied Civil Engineering at Graz University of Technology and graduated in 2001. After 2 years as a geotechnical engineer, I returned to the Institute of Rock Mechanics and Tunnelling as a university assistant and finalized this period with my doctoral thesis in the field of monitoring data evaluation in tunnelling. For the following 11 years I worked for Amberg Engineering AG in Switzerland as director of the tunnelling division and was involved in several international underground projects including a permanent residence in Chile for a large hydropower project. Since 2020, I'm back in Austria and joined iC consulenten ZT GmbH as a partner. Even though I spend most of my time on management tasks, there is still time for working on projects and technical challenges that I wouldn't want to miss. One of these challenges is BIM which is a great chance for innovation in our business.

**Gamal Heikal**

With a great passion for civil engineering, I finished my bachelor's degree in Cairo followed by a post graduate diploma focused in the area of hydraulics and water resources. However, after starting my master's degree in the Geotechnical and Hydraulics program at TU-Graz, my attention got altered towards the field of rock mechanics and tunneling. I got fascinated by the tunnelling techniques and their challenges towards the unpredictability of nature. Currently, I am working on my master's thesis attempting to enhance the analysis methodology of the TBM advance data in order to find better correlations with the driven rocks. In future, I plan to follow my passion by doing my PhD along with acquiring practical experience in the same field.

**Patrick Ulbl**

My technical interest was already awoken early by tinkering with my father, learning how to practically handle tools. This came in helpful later when I joined him on various construction sites in Poland and Germany which was shortly after I decided upon a technical career by enrolling in an upper high school for mechanical engineering. In school I realized, while enjoying the subjects, that I found no love for the carried out projects and internships. Therefore, after graduation, I chose a university field with a more unique and diverse outlook – civil engineering. In the years as a bachelor student I found and developed my interest for the ingenuity of technical solutions and (material and human) resource management. This was further enhanced by the opportunity to do an internship at the Carinthian Koralm-Base Tunnel, where I have been working to this day in site supervision. My work-relationship plus the aspects of tunneling, doing a great deed for society, let me to choose rock mechanics and tunnelling as my major subject. Following up this decision and to broaden my horizon, I joined the interdisciplinary team of the STEIRIS project in the course of my master's thesis. This project's goal is to achieve a closer look on the topic of rock falls in close collaboration with the federal state of Styria.

# Diary of Events

**Barbarafeier**
Graz, Austria (2021/11/26)

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

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

Symposium by the Austrian platform ATC² (Austrian Tunnel Competence Center), a collaboration of Graz University of Technology and Montanuniversität Leoben. The aim of the symposium is to transfer innovative ideas and know-how in tunnelling. In German. The period for abstract submission ended with March 31st, 2021. The 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)

Lecture by the Head of the Geophysics Department at 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 such an event, or it will take online. Registration via email addressed to tunnel@tugraz.at.

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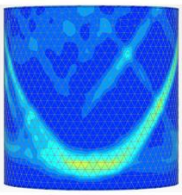
- **Mission to the Mars (supervisors: G. Erharter, G. Grömer (OeWF))**

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.

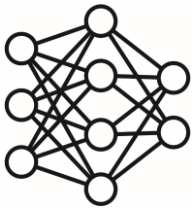
- **Artificial rock samples / Anisotropy (supervisor: M. Winkler)**

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 (supervisor: S. Stauder)**

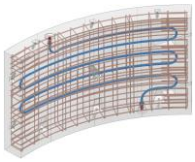
Have you ever wondered what the difference between a stone and soil is? This question is more difficult to answer than expected and is the focus of the research field Hard Soil-Soft Rock (HSSR). Therefore, many engineering problems in geotechnics can be linked to excavations in hard soils or soft rocks.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

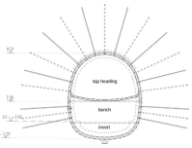
# Have a look at our Master‘s Theses II



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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