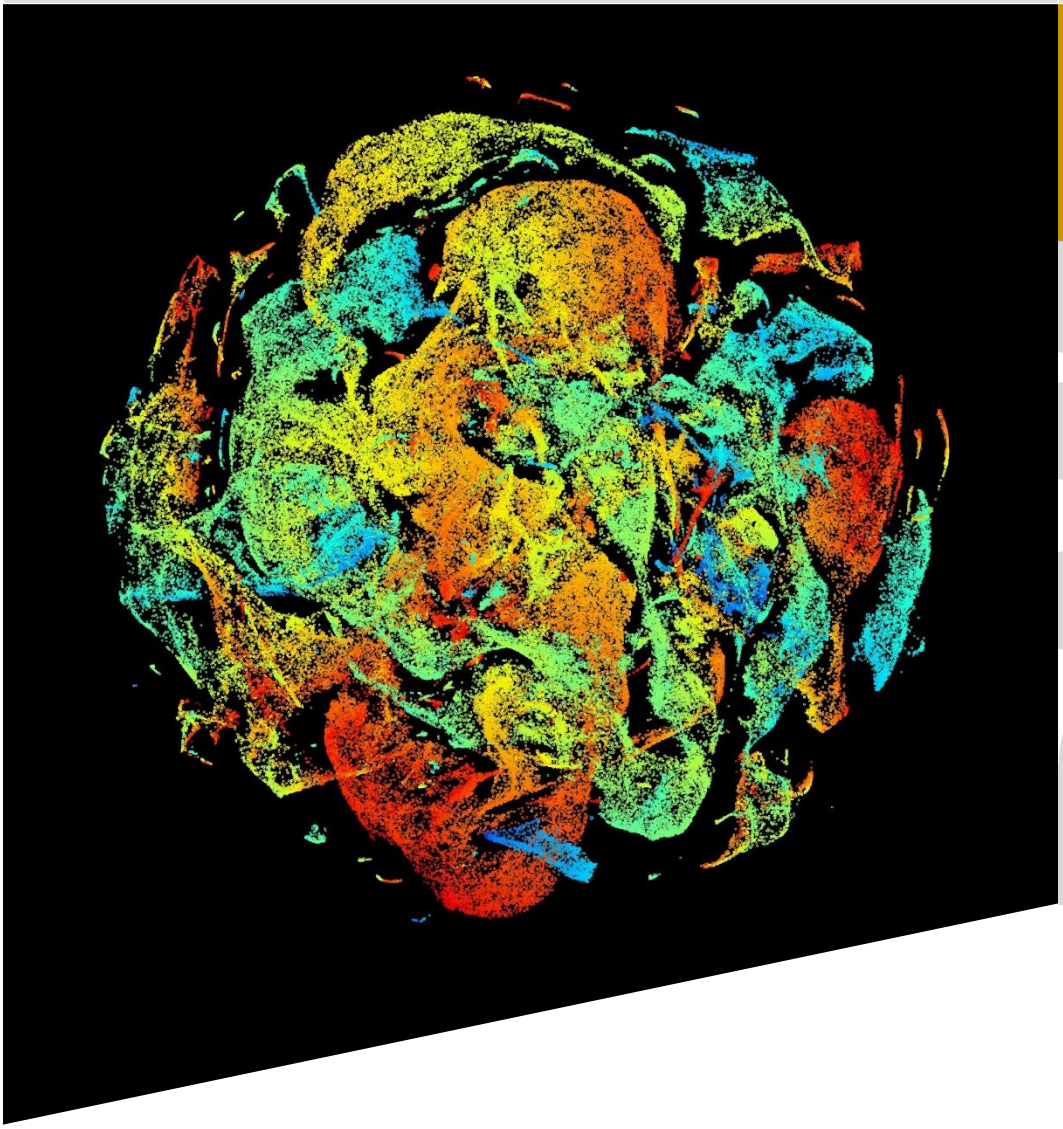
ROCK REPORT

Mechanics & Tunnelling

Quarterly Newsletter of the Institute of Rock Mechanics and Tunnelling

01 Volume 1
April 2020

IRMT



NAWI Graz
GEOZENTRUM

TU Graz
Graz University of Technology

MLGT
Machine Learning in Geotechnics

Content

Marcher's Column

Rock Report was born as an idea to give our students, partners, friends and colleagues an insight into our institute life. News on teaching, research and other activities are in the foreground and will be published quarterly.

The first quarter of 2020 presents us all with an unexpected, huge challenge, and it is not yet clear how long COVID-19 will haunt us. I am fascinated how we all deal with this extraordinary situation. We find ways and possibilities to master our daily life despite all the limitations. As scientists and lecturers, it is our obligation to continue teaching and research in such times. Online programs, teaching videos and platforms are a great support for us. And the current crisis may also represent an opportunity: do we constantly have to be on the move around the world to keep up with the latest research? The situation shows us an alternative: time for high-quality journal papers, commentaries in magazines, discussion in online forums and communication networks offer unique opportunities without wasting resources unnecessarily.

In this first issue of the Rock Report you get informed on our new teaching and research topics: learn more about our "Onsite-Shotcrete Course" and our new lecture "Applied Data Analysis for Geotechnics". Discover with us "A Tunnel as a Thermocluster", "Machine Learning in Geotechnics", the special challenges of "Hard Soil / Soft Rock" and have fun with our "Mission to the Mars".

Best regards, stay healthy, Glück Auf!

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Title Picture:
The title image depicts 12 km of TBM data processed with a TSNE dimensionality reduction algorithm.

9 April 2020 – published
Georg H. Erharter – editor in chief
tunnel@tugraz.at – contact

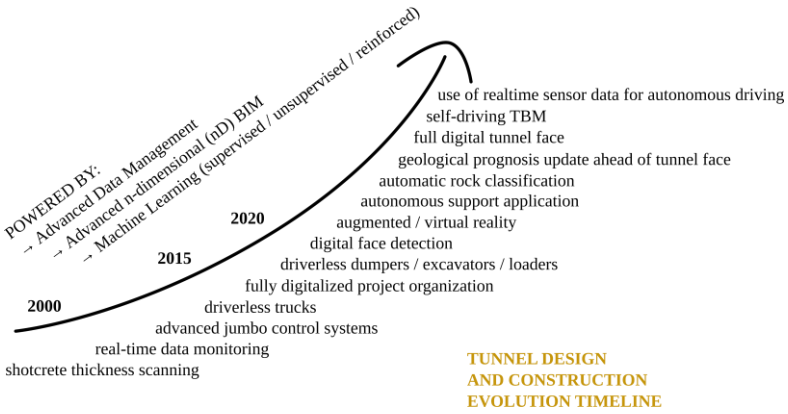
Research Overview

RMT moves forward

In 2018 Prof. Thomas Marcher took the lead of the Institute of Rock Mechanics and Tunnelling (RMT) at TU Graz and complemented the main research by forward-looking subjects. As the demand for underground space will increase, research focuses on urban underground engineering and related challenges such as hard soil/soft rock mechanics and anisotropic rock behaviour.

To accomplish research goals and to analyse data efficiently, the RMT staff uses digital tools emerging from developments in the AI science (e.g., machine learning). Introducing such tools in geotechnics is one task of the MLGT group ('Machine Learning in Geotechnics'), a collaboration of researchers from the RMT and the Institute of Soil Mechanics, Foundation Engineering and Computational Geotechnics headed by Prof. Roman Marte and Prof. Franz Tschuchnigg. The MLGT-group already published first results, e.g. [Link].

But RMT responds also to needs for research arising at civil engineering projects and contributes to global challenges. Our staff transfers findings from acoustic emission lab-tests to construction sites to give warnings ahead of sudden rock burst events at great depths (e.g., in mines). Other staff members start to find the optimum combination of tools for an automatic survey of inner tunnel linings as manual inspection of existing tunnels consumes a lot of resources worldwide. However, existing underground structures not only cause costs, they can also be used to gain eco-friendly energy heat. A related project started recently at the Brenner Base Tunnel project (ThermoCluster BBT). There is a lot to do and many yet unknown challenges will arise on the way to the solution, but the RMT staff being motivated and confident keeps moving.



Taken from Marcher, T., Erharter, G.H. and Winkler, M. (2020), "Machine Learning in tunnelling – Capabilities and challenges", Geomechanik und Tunnelbau, Vol. 13, No. 2, pp. 191–198. DOI: 10.1002/geot.202000001

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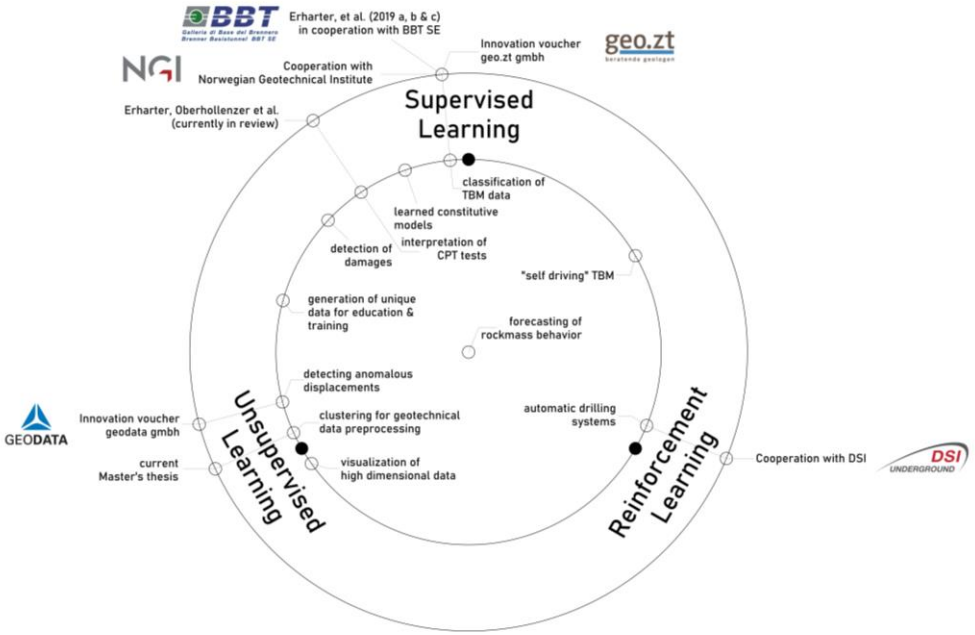
Research Focus Today

Machine Learning in Geotechnics - MLGT

Today's scientific studies and modern construction sites are increasingly characterized by large amounts of data. Whereas many people see this as a problem, we see this as a chance to gather undetected insights and find never before recognized relationships by systematic data analysis and the deployment of modern Machine Learning algorithms.

To pursue this goal, the Institute of Rock Mechanics and Tunnelling founded the research group "Machine Learning in Geotechnics" - MLGT, which explores applications of Machine Learning to solve problems in the intersection of big data and geotechnics. As these problems are not confined to rock mechanics or tunneling, MLGT was shortly after joined by the Institute of Soil Mechanics, Foundation Engineering and Computational Geotechnics and is now run under the leadership of Georg H. Erharter (PhD Student), Prof. Thomas Marcher and Prof. Franz Tschuchnigg.

The research group's first projects were mainly using methods of supervised Machine Learning, where an algorithm is trained to fulfill a certain task by learning from data. It was for example possible to train an algorithm to successfully classify rockmass behavior only based on tunnel boring machine data. Future endeavors however, will go more in the direction of unsupervised- or even reinforcement learning, as there are certainly also many possible applications in these fields.



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Recent RMT Guests

R. Gardenghi

On the 27th of February the institute had the great pleasure to host Professor Roberto Gardenghi, El.Ing.Dipl. EPFL. He is the head of the division of applied photonics and optoelectronics of the institute for systems and applied electronics at the University of Applied Sciences and Arts of Southern Switzerland (SUPSI). His research areas are “Sensors and systems for monitoring natural risks and constructions” and “Application of optoelectronic and photonic technology on sensors”.

His visit was part of a planned cooperation regarding various research subjects such as “Monitoring rock that is prone to rock burst”, “Monitoring of rock slopes”, “Wireless sensors for the inner and outer lining of shotcrete for long-time monitoring”, “Detection of water behind the inner and outer lining of shotcrete” or “Survey of existing infrastructure (tunnel linings, retaining walls)”.

We enjoyed his company and are looking forward to a beneficial cooperation between our institutes.

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M. Cudny

In September 2019, Prof. Dr. Marcin Cudny from Gdansk University of Technology (Department of Geotechnics, Geology and Marine Civil Engineering) visited our institute in Graz to give a presentation and share his experience in the field of constitutive modelling of anisotropy in geomaterials. The past decade he has devoted parts of his work to the development of a hyperelastic modelling framework to simulate different aspects of anisotropy in overconsolidated soils. His concept enables the consideration of stress-induced anisotropy in a natural unforced way and further covers structural anisotropy which arises from the presence of a horizontal layering in soils or bedding and cleavage planes in rocks. There is now a cooperation between Dr. Cudny and the Institute of Rock Mechanics and Tunnelling which focuses on examining the applicability of the hyperelastic framework to practical problems in rock mechanics.

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Teaching Highlights

Applied Data Analysis for Geotechnics

Over the last few years we were able to see a rise in the application of machine learning techniques, for the purpose of data evaluation, also in the field of Rock Mechanics and Tunnelling. As a consequence, programming skills have become an essential prerequisite for geotechnical engineers working in scientific research as well as Master's student writing their theses. To equip students with the required tools, the Institute of Rock Mechanics and Tunnelling launched a new course that conveys basic Python programming skills with special focus on geotechnical applications. A first pilot course which was held in the summer term 2019 already was a big success. The next course will take place at the end of May / Beginning of June 2020.

For further information visit [LINK]

or contact winkler@tugraz.at or erharter@tugraz.at

Shotcrete Course


Lukas Gottsbacher

In modern tunnel construction, the use of shotcrete is absolutely necessary and widely used worldwide. In order to better understand this material and its applications and to gain practical experience with it, the Institute of Rock Mechanics and Tunnelling together with the Chair of Underground Mining at the University of Leoben are organising the "Shotcrete Course". The course is aimed at students of the lecture "Advanced Rock Mechanics and Tunnelling 2" and takes place at the "Zentrum am Berg" (ZaB) in Eisenerz. Topics of the course are the use of a shotcrete spraying machine for dry shotcrete and a simulator for wet shotcrete, as well as theoretical basics. It is a shortened version of a similar course of the VÖBU. The planned course date is 13 May 2020.

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Site Reports

CPT tests at the limit

Cone penetration testing (CPT) is an in-situ method usually used to determine geotechnical ground properties of soft fine grained soils. Due to its fast and cost-efficient applicability, it could also be considered as a tool to estimate ground parameter of hard soils or soft rocks. To explore the limits of conventional CPT devices an intense testing campaign was conducted at the construction site of the Fürstenfelder Schnellstraße S7 in cooperation with ASFINAG, GEO-PRO and the Institute of Soil Mechanics. The prevailing geological indication of the investigated ground shows clayey, silty and sandy soils with embedded layers of clay-, silt- and sandstones. After a visit and a productive exchange at the Norwegian Geotechnical Institute in Autumn 2019 the machinery was pushed far beyond the specified limits and several measures to ease the ground penetration like friction reducers, lubrication and different tip geometries were tested.

Pusching the limits requires unconventional methods:
here an excavator prevents a CPT testing machine from taking off.

The results show that cones with a cross section of 15 cm² require less energy to penetrate the ground and outclass cones with 10 cm² or 24 cm² considering the sounding depth. Furthermore, an expansion of the thrust hole with friction reducers can lead to an increase in penetration depth of up to 30 %. The studies also show that cones with smaller aperture angle (40° or 50° instead of 60°) lead to a lower thrust force and therefore can increase the maximum sounding depth. Although there were minor setbacks and problems to overcome due to the permanent sounding at the absolute limit the results look promising and will be collected and evaluated in a Master's Thesis to form the basis for further research regarding in situ testing methods on hard soils or soft rocks.

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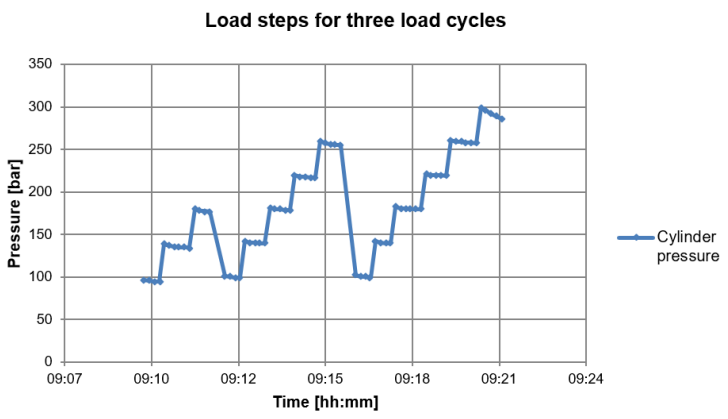
Site Reports

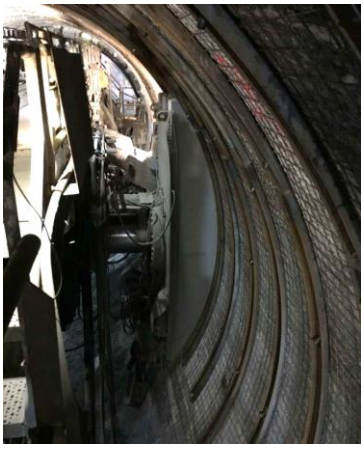
BBT gripper tests

An open gripper TBM continuously records gripper forces. This gave rise to the idea of using these recordings to determine the rock mass stiffness of the surrounding ground by using the gripper as plate load tests comparable to the devices used in soil mechanics.

One of our master students, Gerd Sackl, seized the opportunity and completed in 2019 an internship for the Brenner Base Tunnel SE at the construction lot Tulfes-Pfons close to Innsbruck, which was awarded to the Strabag/Salini-Impregilo consortium. At this lot a 15 km long stretch of the exploratory tunnel, which is constructed ahead of the main tunnels, is excavated by an open tunnel boring machine (TBM).

In close coordination with RMT Gerd Sackl developed two different in-situ test procedures upon constant agreement with the client, the contractor and the site supervision team: tests with one load cycle and tests with three load cycles. Distributed over a length of 520 m and a time span of 1.5 months, 20 gripper tests have been executed.





Left: Gripper load steps for three load cycles; right: gripper in action [© G. Sackl]

After this internship at site, Gerd Sackl prepared his master thesis based on the obtained data. The evaluation of the rock mass stiffness (deformation moduli) indicated good agreement with the characteristic stiffness values for the rock mass from the lab tests during the design stages reported in the geotechnical reports. The in situ test data and the evaluation of the gripper tests have been discussed and an interpretation on the meaningfulness of the different results were given. Finally, possible modifications on the gripper-TBM and an outlook on further research requirements on the evaluation of the monitored gripper data have been proposed. Gerd Sackl finished his Master Thesis end of 2019 and a conference paper has been submitted for the ARMA conference 2020 (LINK).

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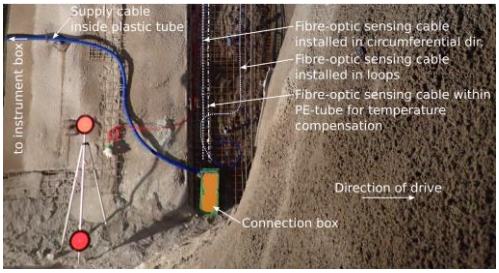
Publications & Presentations

Since Professor Marcher took over the management of the Institute, numerous scientific publications as well as presentations by different employees have been produced at the Institute or Rock Mechanics and Tunnelling. All publications are listed chronologically on our homepage. Selected papers and presentations are presented here.



Direct and Distributed Strain Measurements Inside a Shotcrete Lining: Concept and Realisation

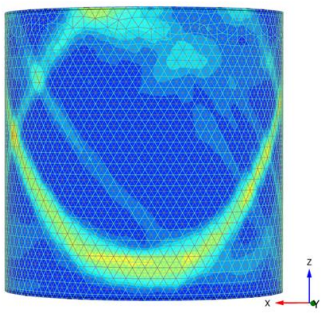
Wagner, L., Kluckner, A., Monsberger, C., Wolf, P., Prall, K., Schubert, W. & Lienhart, W. (Rock Mechanics and Rock Engineering - 2019) Open Access

https://doi.org/10.1007/s00603-019-01923-4

This paper introduces the successful implementation of a fibre-optic sensing system for direct and distributed strain measurement within the shotcrete lining of a conventional tunnel drive. The shotcrete lining of the top-heading and the invert are equipped with two layers (rock side and cavity side) of fibre-optic sensing cables installed in circumferential and longitudinal direction. All cables are measured autonomously for several weeks to capture the strain evolution inside the lining from the day of the construction to a posterior, well-hardened state. An additional follow-up measurement is conducted 2 months afterwards. The measurements enable an assessment of the strain distribution [...]

The brittle to ductile behavior of "hard soil and soft rock" - experimental review and challenges for constitutive modelling

Stauder, S. Marcher, T. (ISRM Congress 2019 - 2019)



Hard soils and soft rocks are part of engineering problems world-wide. They cannot be characterized by classical descriptions of soils and rocks. The mechanical behaviour pre-peak is strongly governed by the applied confining stress. In the postpeak regime localization occurs in a brittle or a ductile mode. The main work presents the application and comparison of two constitutive laws described in different elasto-plastic frameworks: a Hardening Soil model, which fits better to the behavior of soils and a Concrete model, which should describe the mechanical behaviour of rocks better. However, the contribution is focused on the determination and calibration of decent input parameters for the use of the Concrete model (implemented in PLAXIS) in modelling hard soil – soft rock material.

Artificial test samples for the replication of soft rock anisotropy

Winkler, M. (Konferencja Korbielow - Feb. 2020)

Usually, the mechanical behaviour of anisotropic rocks is studied in terms of destructive laboratory tests on natural specimens. Natural sample inhomogeneities, however, complicate the interpretation of the acquired testing results especially in case of foliated and bedded rocks, which display a directional dependence of mechanical properties. To overcome these limitations an experimental investigation program was launched focusing on the production of artificial replicates of layered rocks. In first studies homogenous samples were manufactured to optimize the basic cementitious mixtures. In a second step, layered composite blocks using layers of different mixtures were produced from which oriented samples were extracted. The subsequent performance of UCS tests in 15° bedding plane intervals clearly depicted an anisotropic behaviour in terms of stiffness and strength.

Faces

Elena Theußl

I started studying Civil Engineering and Construction Management in 2015. My interest in tunnelling began with an internship at one of the world's largest tunnel construction sites during my first year of studying. I was impressed by the need to constantly adapt to uncertainties and find new solutions on the spot. After finishing my bachelor's degree with a project on rock burst I started the master's programme Geotechnical and Hydraulic Engineering, with a focus on rock mechanics and tunnelling. Currently, I am working on my master's project trying to correlate TBM data with the data of exploratory drillings. I will finish my studies by the end of this year and look forward to continuing working in the field.

Alexander Meier

As Technical University Graz Alumni and former project assistant at the Institute of Rock Mechanics and Tunneling I can look back on an exciting and instructive time. My increasing fascination for the various subfields of tunneling with special regards on tunneling in challenging geotechnical and geological conditions led to the topic of my master thesis. During several experiments on models I carried out, I was able to develop a deeper understanding of the influence slickensides and joints have on failure mechanisms in cavity structures. Since I launched my career two years ago for Amberg Engineering AG as a geotechnical engineer at the Semmering Base Tunnel Project Lot 2.1 for the Austrian Federal Railways we already faced a significant number of challenging geotechnical and geological conditions. My fundamental knowledge concerning rock mechanics and failure mechanisms gained at Graz University of Technology has been proven useful and very advantageous various times in the daily interpretation of monitoring data, geotechnical models and for developing solution-orientated concepts set in place at my current project.

Christian Wallner

I planned on choosing the Geotechnical and Hydraulic Engineering Master courses the day I started here on TU Graz. The broad variety of subjects offered, panders the interests of many students and gives them the opportunity to specialise even further which made it possible for me to increase my understanding of my preferred field of geotechnical engineering. Being able to take various soil and rock mechanic classes led me to the fascinating topic of hard soil soft rock mechanics. I am currently in the process of finalising my master thesis on the institute of rock mechanics and tunnelling, which deals with finding a specialised concrete material model as an application for HSSR materials. It will, after theoretical and numerical research, also consider its implementation in practical use in state-of-the-art engineering.

Markus Pötsch

I studied civil engineering at Graz University of Technology and Universidad de Granada with specialisation in geotechnical and hydraulic engineering. After graduation and working as a geotechnical engineer I joined the Institute for Rock Mechanics and Tunnelling for a research initiative whose objective was the development of a 3D imaging system for the acquisition of geotechnical data and their rock mechanics analysis. During this period I also completed the dissertation about failure modes in jointed, hard rock. Today I am still involved with 3D imaging technology at 3GSM and dedicate myself to the system development, marketing and sales, on-site implementation and training for the mining and tunnelling professionals. Working at the edge of high technology is exciting and challenging but also a creative and highly rewarding activity.

Diary of Events

Rock Slope Destabilization – Permafrost
Online (postponed – new date to be announced)

Lecture by Dr. Michael Krautblatter (professor at Technical University of Munich) about laboratory tests, geophysical field measurements and about a mechanical rock-ice-model to analyze destabilization of rock slopes due to loss of permafrost. In German. Free of charge. Send your registration via email to kluckner@tugraz.at.

TU Graz Geotechnical Lectures

Expedition Mars
Graz, Austria (postponed – new date to be announced)

Lecture by Dr. Gernot Grömer (head of the Austrian Space Forum) about scientific field experiments at desert-like places on Earth to prepare for manned mars missions. In German. Free entry. Send your registration via email to teilnahme@tugraz.at.
[additional information]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The Long Night of Research at TU Graz
Graz, Austria (2020/10/09)

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. The first tour will start at 5 p.m. Registration via email addressed to tunnel@tugraz.at.
[additional information]

HSSR-Workshop
Graz, Austria (2020/11/27)

Mini Symposium on Hard Soil / Soft Rock Material and Anisotropic Behaviour. In English. Abstract submission is still possible. Registration will be opened soon. For pre-registration or abstract submission, please send an email to Mr. Manuel Winkler (winkler@tugraz.at).

Barbarafeier
Graz, Austria (2020/11/27)

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

2nd ATC2-Symposium 2021
Graz, 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. Abstract submission will be possible end of 2020. Registration will be opened in 2021.
http://austrian-tunnel-competence-center.at

ATC² Austrian Tunnel Competence Center
Graz University of Technology | Montanuniversität Leoben

Have a look at our Master‘s Theses

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


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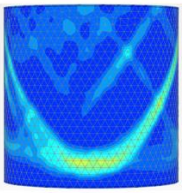
▪Mission to the Mars (supervisors: G. Erharter, G. Grömer (OeWF))

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. This research is a cooperation with the Austrian Space Forum.

▪Artificial Rock Samples / Anisotropy (supervisor: M. Winkler)

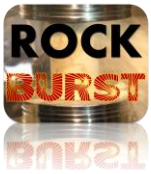
Rock is a complicated material, for example it is very often anisotropic, i.e. its properties are dependent on certain directions. To learn more about this property and to develop a constitutive model for it, numerical simulations are carried out and artificially anisotropic rock samples are tested in the laboratory. Another interesting master thesis is focusing on those artificial samples.

▪Hard Soil Soft Rock (supervisor: S. Stauder)



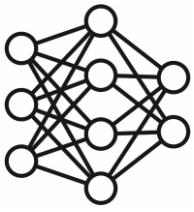
Have you ever wondered what the difference between a stone and soil is? This question is more difficult to answer than expected and is the focus of the research field Hard Soil-Soft Rock (HSSR). The topic of a master thesis in this area is the harmonisation of the nomenclature used in earthworks in connection with hard and soft stone. Supervisor is Stefan Stauder. To further investigate this topic, a soft rock triaxial testing machine is installed in the rock mechanics laboratory.

▪Rockburst (supervisor: L. Gottsbacher)



A completely different topic is focusing on a danger on the construction site, rock burst. This hazard is very dangerous because it is sudden and extremely violent. The aim is to study rock burst events on site and to develop test equipment to predict it and reduce its damage to workers and equipment. An example of a violent rock burst event can be found under this QR code.

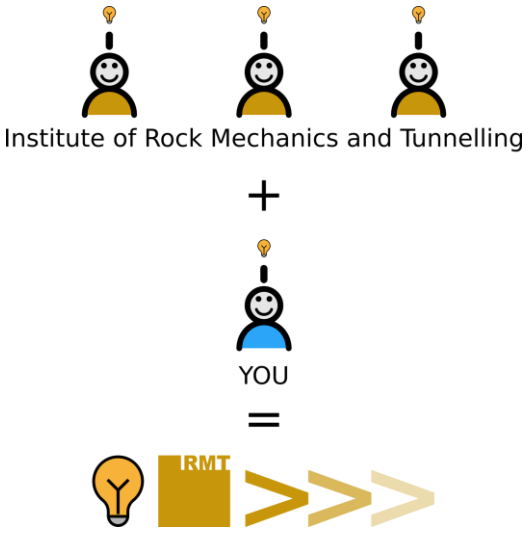
▪Machine Learning (supervisor: G. Erharter)



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).

In addition to these main research areas, further master theses are supervised, which can be found on the website. These include a numerical approach to classifying rock masses, a study of Building Information Modelling (BIM) in conventional tunnelling with respect to the tunnel face and an engineering-geological mapping of slope debris over mountain streams as input for risk assessments with respect to debris flow events. [overview of master's theses]

Open Positions at RMT



YOU, that is

- A female post-doc in the field of Civil Engineering, Computer Science or related field with a special focus on Geotechnics / Tunnelling with in-depth knowledge of Data Science / Artificial Intelligence. Submit your application for a fully funded position as assistant professor until April 30th, 2020. >>> [LINK]

- A PhD candidate with interest in testing of rocks, and having a knack for operating sensitive testing machines. Send your application for the fully funded part-time position to Prof. Marcher any time. >>> Email to thomas.marcher@tugraz.at

- A civil engineer with experience in inspection and maintenance of tunnels interested in writing a PhD thesis. Many research questions exist and wait to be answered by you. Funding possibilities depend on your current employment situation. Tell us your interest any time and we will find a funding. >>> Contact Prof. Marcher (thomas.marcher@tugraz.at, +43 316 873 8114)

JOIN RMT – we'd love to welcome you.

Cooperation

… please contact us in case we forgot you here


… moving
forward
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