ROCK REPORT

Mechanics & Tunnelling

RMT

IRMT

NAWI Graz GEOZENTRUM

TU Graz.
Graz University of Technology

MLGT
Machine Learning in Geotechnics

Content

Marcher's Column

"We have made climate change – and we as tunnel and underground construction specialists are now called upon. We're the scientists and engineers…" Arnold Dix, ITA president, used this words in the opening speech of the World Tunnel Congress 2023 in Athens.

The future is underground! Many innovative projects worldwide point to this trend. There are many examples of sustainable and environmentally friendly underground construction projects, also in the Central Alps: "Cargo Sous Terrain" in Switzerland, mega pumped storage plants like the Lünerseewerk II, Illwerke (Austria) or even the solution for Salzburg's traffic, the so-called S-Link project. In urban areas, there are many possibilities to put not only transport but also other civil structures such as water, sewage, energy and entire industrial buildings underground. This preserves the earth's surface for humans! Underground storage does not only refer to dangerous goods like nuclear waste, but also to the storage of water (e.g. district heating) or fuels like hydrogen and gas. A promising technology in this context is the use of underground infrastructures - such as tunnels -, as "geothermal power plants". The use of geothermal energy underground is becoming increasingly important!

Our new edition of the Rock Report also follows this trend: The topics of the 2nd joint NGI - TU Graz workshop "Advances in Geotechnical Engineering" focused on innovations, material efficiency and sustainable solutions. A guest lecture by Bernd Raderbauer from Marti Tunnel AG dealt with logistics and sustainable material management in the construction of the Linth-Limmern power plant. "Green Automated Tunneling" was the topic of the newly introduced cross-university dissertation seminar held in Vienna. One of our research activities deals with the use of sensor data from automated drilling at the tunnel face to increase efficiency in NATM tunnelling. One of our recent Master's graduates dealt with the topic of optimising blasting operations at the tunnel face using MWD data.

Many other topics are reported on below. It is fascinating how many things happen in a quarter of a year. I would like to thank the entire RMT team for their excellent work!

To all of you, enjoy reading the new Rock Report.

Glück Auf!

Thomas Marcher

Research Focus

2. NGI – TU Graz Workshop: Advances in Geotechnical Engineering

The second workshop of the cooperation of the Norwegian Geotechnical Institute (NGI) and RMT, supported by IBG, took place on April 21st at the TU Graz. 14 contributions to the workshop topic "Advances in Geotechnical Engineering" were presented and discussed in five sessions.

Thematically we started Session A with a lecture by A. Sapronova and P. Unterlass on unsupervised learning / rare data. This was followed by A. Lysdahl on semi-automatic interpretation of airborne geophysical data and bedrock surface modelling. G. Erharter and S. Oberhollenzer finished off the first session with a talk on MLPFEM – towards Machine Learning based Parameter Calibration for Finite Element Modelling.

Session B comprised RMT's research topics of I. Metzler, T. Frühwirt, T. Marcher on HSSR in-situ tunnel strategies as well as M. Winkler on Anisotropy.

L. Piciullo kicked off Session C with a lecture on IoT based monitoring and modelling of slope stability, followed by R. Kienreich on rockfall risk. In addition to these two, R. Marte finished the block addressing slow moving large landslides.

Session D comprised three topics, begun by P. Paniagua on recent advances for implementation of interpretation of CPTu in clays and silts, followed by IBG's L. Hauser, H. Schweiger, S. Oberhollenzer on the characterization of fine-grained soils by means of in-situ tests, laboratory tests and numerical analysis, and finished by I. Marzouk on APD – from in-situ tests to soil parameters.

In the last session of the day, T. Geisler presented his ThermoCluster project, S. Gjengedal elaborated on the potential for geothermal energy exploitation in Norwegian tunnels, and S. Ritter finished with the topic of green soil stabilization ("GOAL").

Following the technically ambitious day program, we took a guided city tour through the old town of Graz and enjoyed a dinner with specialties of the Austrian cuisine together.

On Saturday, we were able to show our colleagues from NGI a part of beautiful Styria in and around Riegersburg, touring the castle and including a special birds of prey show, as well as satisfying the sweet tooth by a tasting tour through the Zotter chocolate factory. The day was ended comfortably and relaxed at Genusshotel Riegersburg, taking advantage of their wellness area and enjoying another gourmet dinner.

Site Visits

Master Builders Solutions' Shotcrete Workshop at Hagerbach Test Gallery

From April 26th to April 28th, Master Builders Solutions hosted their biannual global Sprayed Concrete Workshop course at Hagerbach Test Gallery in Switzerland. Representing RMT, Ines Metzler was invited to join and experience the hands-on workshop addressing parameters and aspects of sprayed concrete application in tunnelling and mining. The workshop was alternating between theoretical input and practical sessions, and comprised a broad spectrum of subjects, such as implementation of sprayed concrete for rock support, mix design considerations, concrete testing, application techniques, strength development, Alkali-free accelerator technology as well as sustainability aspects of sprayed concrete. On Thursday night, we got to enjoy a special dinner at Sargans Castle, take in the picturesque view over the Swiss mountains and connect with the participants from 14 different nations and technical backgrounds.

We want to thank Wolfgang Aldrian and the Master Builders Solutions team for inviting us to this interesting event and sharing their technical expertise on all things shotcrete!

Angath Adit Site Visit

RMT's research project ChaMod-HSSR (cf. RR 03/22) (Characterization and Modelling of Hard Soil/Soft Rock considering Anisotropy and Swelling Potential) comprises, among other objectives, extensive rock mass observation and monitoring campaigns during the excavation of an exploratory tunnel. Construction has already started and tunnel excavation is scheduled to commence soon. The lithology to be studied in the course of the project is already visible in the embankments, thus the rock mass observations carried out by RMT were initiated with a first site visit in June.

This time, we were able to study the rather weathered, surficial sections and are excited to what the tunnel drive will bring in the next months.

Publications & Presentations I

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

Building information modelling based ground modelling for tunnel projects – Tunnel Angath/Austria
Erharter, G.H., Weil, J., Bacher, L., Heil, F., Kompolschek, P. (Published in Tunnelling and Underground Space Technology 2023 – [Open Access](*))

The trend for digitalization in geotechnics and tunnelling of the past decade has been spearheaded by building information modelling (BIM). However, BIM ground modelling remains a challenge since the inherent heterogeneity and uncertainty of the underground are challening to model. This paper presents a new framework for ground modelling in BIM. A split of the BIM ground model into several "sub models" is proposed: the "factual data model", a "geotechnical model" and the "geotechnical synthesis model". The proposed BIM ground modelling concepts are based on current international developments (e.g., DAUB / German ITA branch, or IFC Tunnel). After presenting this theoretical context, the case study of the Austrian Tunnel Angath is given where state of the art BIM ground modelling was done in the planning phase of the project. Although the modelling for this project is seen as a success, it has highlighted several deficits that hamper the industry wide adoption of BIM in ground modelling. It is concluded that BIM ground modelling is beneficial for the tunnelling industry as it contributes towards more standardized and comprehensible working processes and an enhanced decisions basis.

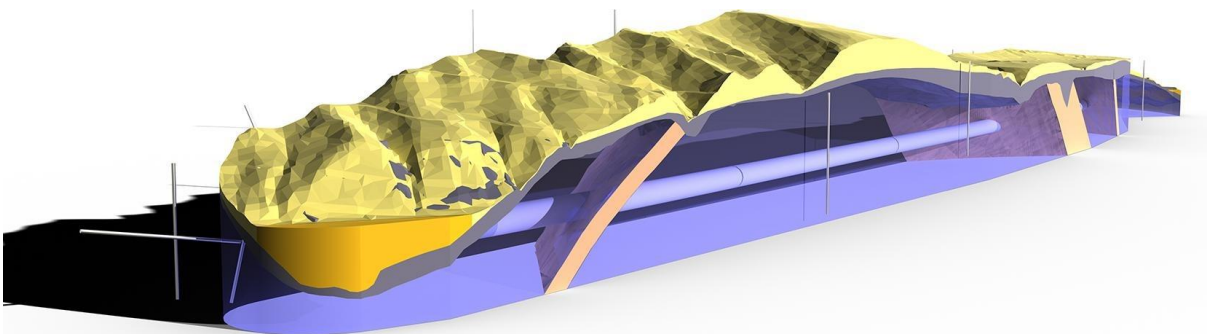An exemplary IFC file of a BIM ground model can be found on the TU Graz repository [here]().

Figure: The BIM ground model for the "Tunnel Angath" in Tyrol / Austria.

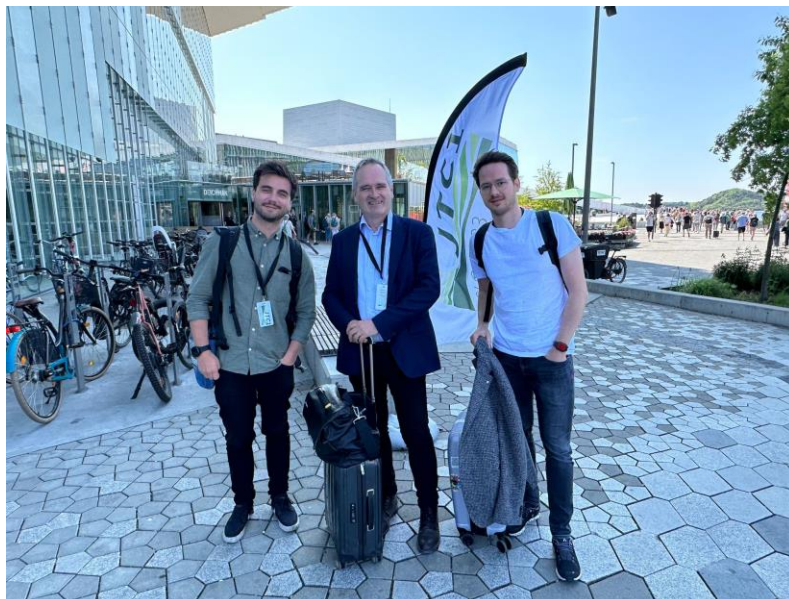# Publications & Presentations II

JTC1 Workshop – Invited Lecture

Potential for remobilization of debris fans

Marcher, T., Geisler, T., Winkler, M. (JTC1 2023 – Session 3 – Numerical Modelling of Landslides)

On June 8, 2023, Professor Marcher, along with his two coworkers Thomas Geisler and Manuel Winkler, had the privilege of being invited to deliver a lecture at the "3rd JTC1 Workshop on the Impact of Global Changes on Landslide Risks." This significant event was held in Oslo, Norway, this year. The excellent workshop, hosted by the Norwegian Geotechnical Institute (NGI), took place in the impressive lecture hall of the Deichmann Library. During their invited lecture, Professor Marcher and his team provided valuable insights into a most recent study conducted on the stability of debris fans in high-alpine regions. Throughout the workshop, a consensus emerged among participants that the ongoing climate change and other anthropogenic factors will lead to an escalation in the risk of landslides to our society. Consequently, there is a growing necessity for the development of more advanced methods in risk detection, risk assessment, landslide characterization and prediction including risk mitigation.

Connected improvements will play a crucial role in accurately estimating the collaborative efforts required, particularly in coordination with infrastructure providers. Moreover, they will contribute to creating a secure environment that prioritizes the safety of our societies.

Publications & Presentations III

Underground Construction Prague 2023

Strategy optimisation for tunnel excavation based on compositional data correlation

Sapronova, A., Unterlass P. J., Marcher, T. (oral presentation at Underground Construction Prague 2023)

The 15th International Conference, "Underground Construction Prague 2023," took place in Prague from May 29 to May 31, 2023. Hosted by the Czech Tunnelling Association ITA-AITES, with support from ITA-AITES, ISSMGE, and ISRM, the conference brought together experts in the field. The event included a technical exhibition, a poster session, and site visits to various underground structures in Prague, such as Line D of the Prague Metro, the Urban Traffic Control Centre (UTCC Prague), and the Rudolph Adit and old wastewater treatment plant.

The Institute of Rock Mechanics and Tunneling contributed with a research paper titled "Strategy optimisation for tunnel excavation based on compositional data correlation analysis." by A. Sapronova, P. J. Unterlass, and T. Marcher. The paper was complemented by an oral presentation delivered by A. Sapronova.

The research presented an approach for the preprocessing and analysis of MWD (Measurement While Drilling) data, aiming to enhance the precision and resilience of machine learning models used for predicting rock mass conditions. The study underlined a procedure for pattern extraction from data during preprocessing. This was achieved by applying a correlation analysis to compositional log data derived from blast hole drilling. This method fused correlation analysis and unsupervised clustering techniques to create training datasets for machine learning-based models. The resultant clusters were subsequently employed as input features for machine learning algorithms.

Publications & Presentations IV

The 17th Danube – European Conference on Geotechnical Engineering

Rare events detection in underground construction: an overview and evaluation of machine learning approaches

Sapronova, A., Unterlass P. J., Marcher, T., Dickmann T., Hecht-Méndez J. *(Poster session at The 17th Danube – European Conference on Geotechnical Engineering)*

The 17th Danube – European Conference on Geotechnical Engineering (17DECGE) was held in Bucharest, Romania from June 7 to June 9, 2023. Hosted at the Ramada Parc hotel and supported by the Romanian Society for Soil Mechanics and Foundation Engineering (SRGF) and leading technical universities in Romania, the conference aimed to bring together geotechnical experts from Danube – European countries. It focused on discussing specific and shared practices within the European context, promoting knowledge exchange, addressing research and practical topics, fostering transdisciplinary discussions, and providing a platform for constructive discourse.

RMT contributed with the paper "Rare events detection in underground construction: an overview and evaluation of machine learning approaches," co-authored by A. Sapronova, P. J. Unterlass, and T. Marcher and T. Dickmann, J. Hecht-Méndez from Amberg Technology. The paper focused on the use of artificial intelligence and machine learning (AI/ML) for predicting rare events by addressing issues like sparsity and class imbalances in geotechnical data. The study highlighted the efficacy of data re-balancing using unsupervised methods. That resulted in the improvement of the accuracy of AI/ML models by 10%. The study detailed how these advancements can be applied to predict rock mass classes ahead of the tunnel face using seismic data. To address the problem of data oversampling, the team employed the SMOTE and GAN methods for each rock mass class and rock type. This oversampled data was used strictly for training, while testing was conducted exclusively on real data.

The findings of this paper were further communicated via a poster presentation during the conference, fostering a deeper understanding of the potential of AI/ML in geotechnical engineering

Publications & Presentations V

Trondheim – NTNU & SINTEF

It was an honour to visit NTNU and SINTEF in Trondheim, Norway. The starting signal for future cooperation was already given in November 2023, when Prof. Kristin Holmoy visited us at TU Graz (cf. RR 04/22). In combination with an invited talk at the JTC1 congress in Oslo (cf. JTC1 Workshop, page 6), I was able to spend a whole day in Trondheim on 7 June 2023. A workshop was organised by Kristin Holmoy, where I was allowed to give a talk on: "How does the Institute of Rock Mechanics and Tunnelling work with Machine Learning in the context of tunnelling and engineering geology." Prof Holmoy gave an insight into the NTNU - SINTEF cooperation Gemini Center in the field of tunnelling. Highly interesting presentations by NTNU and SINTEF experts showed the great potential for collaboration in machine learning in tunnelling. In the afternoon, Prof. Krishna K. Panthi and other experts from NTNU and SINTEF organised a tour of their laboratory building. What is possible here in the field of rock mechanics testing is extremely impressive. A wonderful dinner in the city centre of Trondheim concluded this fascinating day. Many thanks to NTNU and SINTEF for their hospitality. I look forward to a fruitful collaboration.

Publications & Presentations VI

NGI Lunch lecture

Unravelling the non-linear and anisotropic nature of soft rocks

*Winkler, M. (NGI Lunch lecture – Norwegian Geotechnical Institute)*

On June 7, 2023, Manuel Winkler and Thomas Geisler, both members of RMT, visited the Oslo office of the Norwegian Geotechnical Institute (NGI). The connection between RMT and NGI had been established approximately four years ago through a series of workshops conducted online and in-person, as well as through research visits made by members of RMT.

Dr. Georg Erharter, a former RMT colleague and now employee at NGI, organized the visit flawlessly. He provided us with a comprehensive tour of the office space and gave us an up-close look at NGI's remarkable rock mechanics laboratory. Moreover, he arranged for Manuel Winkler to deliver a presentation as part of NGI's internal "lunch and learn" session, which received appreciated interest. The presentation focused on the topic of "Unravelling the non-linear and anisotropic nature of soft rocks" and sparked a fruitful discussion.

During the discussions, it became evident that significant challenges persist in characterizing materials of this nature, with many aspects of their behavior originating at the microscopic level. Understanding the mechanisms at the microscale is of utmost importance for future advancements in laboratory and in situ investigations and the development of constitutive models for these stress-sensitive materials.

Many thanks to NGI, and especially to Dr. Erharter, for their great hospitality and for granting us the opportunity to visit their office.
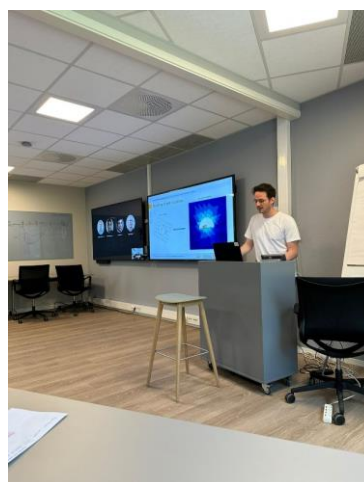
Publications & Presentations VII

IRCAI Global Top 100

RMT new project Data Advance Via INtelligent Content Integration (DaVinci Project) has been recognized as an "early stage" project within the IRCAI GLOBAL TOP 100.

This award acknowledges creative projects that use Artificial Intelligence to help achieve the United Nations' goals for global improvement and sustainability.

The International Research Center on Artificial Intelligence (IRCAI) is a global organization dedicated to the study and development of artificial intelligence. Established under the auspices of UNESCO, IRCAI's goal is to provide a collaborative platform for the AI research community, fostering innovation and addressing ethical, legal, and societal challenges of AI deployment. IRCAI's activities include developing AI policies and guidelines, supporting research in AI and its applications. As IRCAI aims to promote and showcase worldwide solutions, fostering the growth of sustainable solutions platforms. With a strong emphasis on ethical considerations, IRCAI's TOP 100 LIST showcases solutions capable of addressing real-world developmental problems. The review process, managed by the members of the IRCAI Scientific Programme Committees, Scientific Journal Editorial Board, and Business and Impact Council, rigorously vetted each submission, with DaVinci emerging among the top projects.

The DaVinci is a toolkit for accurate data management in civil engineering and advanced processing of technical documentation. It is extracting, structuring, and harmonizing data from civil engineering projects' documentation via intelligent parsing and automatic ontology building. After extraction, the harmonized data is stored in a database and can be used to identify and further explore projects with similar conditions worldwide. Such improvement in knowledge transfer and cross-site information flow enables the proactive management and selection of an effective strategy during the project planning, execution, and maintenance.

The DaVinci designed to enhance data management in civil engineering, and facilitates knowledge transfer and cross-site information flow as a proxy for the proactive management and the selection of effective strategies throughout the lifecycle of a project - from planning and execution to maintenance.

DaVinci has the potential beyond its direct impact on civil engineering: this solution could be adapted for other industries where historical data review and analysis are crucial.

The recognition by the IRCAI marks an important milestone for the DaVinci project, highlighting its potential in contributing towards the realization of the SDGs and revolutionizing data management within civil engineering.

Publications & Presentations VIII

WTC 2023 Athens, Greece

The assessment of intact rock strength for penetration

At the WTC 2023 in Greece Thomas Marcher together with Paraskevi Yiouta-Mitra had the honor of chairing Session 2.2. on Geological, Geotechnical Site Investigation, and Ground Characterization. Beside that, along with his co-authors Wannemacher, H., Hamdi, P., Amann, F., and Frühwirt, T., they presented a paper entitled "The Assessment of Intact Rock Strength for Penetration." during the poster session.

Their paper focused on the intricate relationship between the intact rock and spatially distributed rock joints within a rock mass. Understanding the uniaxial compressive strength (UCS) of the intact rock is essential for estimating feasible penetration rates for tunnel boring machines (TBMs) and predicting excavation rates accurately. However, the failure process of rock specimens under compression can be complex due to internal flaws or heterogeneities on a microscopic scale, which may not be visible to the naked eye. These internal flaws can lead to premature failure and impact the true intact rock strength.

To address these challenges, the authors proposed an engineering approach that incorporates a rigorous filtering process of laboratory results in accordance with international standards and regulations. This method enables a comprehensive determination of the unconfined compressive strength (UCS) to improve penetration rate predictions. By considering the influence of internal flaws and ensuring proper specimen preparation, the authors emphasized the significance of accurate quantification to minimize cost and time implications.

Upcoming Special Sessions

Special session for ISMLG 2023 (Cork, Ireland)

RMT, Montan University Leoben, and Amberg Technology Group are organizing a special session on "Data Quality Assurance and Pre-processing in Geoscience" at the 4th International Symposium on Machine Learning & Big Data in Geoscience in Cork, Ireland from August 29 to September 1, 2023. The session will focus on discussing tools and methods to improve the quality of data used in geoscience, including handling sparse, imbalanced, and mislabeled datasets. The session will present methods for handling data imbalance, errors detection in data labeling, extraction of patterns in data, and assessing the quality of extreme sparse datasets.

Special session for IAMG 2023 (Trondheim, Norway)

RMT will hold a special session on "Rare Events Detection for Risk Management in Geoengineering" at the 22nd Annual Conference of the International Association for Mathematical Geosciences in Trondheim, Norway from August 5-12, 2023. The session will explore tools and methods for rare event detection in geosciences, with a particular focus on risk management and its application in geoengineering. The session will cover various topics, including data sparsity and uncertainty, new findings and techniques for rare events' detection, data preprocessing methods, data imbalance, perceptions and biases in data labeling, and risk modeling.

Upcoming special issues

Geosciences Special Issue "Benchmarks of AI in Geotechnics and Tunnelling"

Driven by a global trend for digitalization, we have seen an explosion of contributions on artificial intelligence (AI) technologies for geotechnics and engineering geology in the past years. In 2018 we – the editors – founded a working group on "Machine Learning in Geotechnics" at the Graz University of Technology, which continues to closely collaborate with the Norwegian Geotechnical Institute up to the present day. While the developments of AI in geotechnics are in line with global trends, we also see deficits that hinder the general advancement of AI technology in our field. An overwhelming number of contributions can be attributed to the field of supervised machine learning, where algorithms learn input-output relationships based on predefined examples though other fields of AI are underrepresented. Furthermore, there is a significant number of studies that are partly or fully irreproducible due to lacking source code and original data.

With this Special Issue, we wish to provide a platform for high-quality contributions from all fields of AI, including but not limited to supervised machine learning (ML), unsupervised ML, self-supervised ML, reinforcement learning, evolutionary computation, and swarm intelligence. The applied geoscientific context of the contributions is set to be very wide, ranging from fields of geotechnics such as slope stability, constitutive modelling, or tunnelling to all applications of engineering geology such as ground investigations, mapping, or geological modelling.

A requirement of contributions is that the associated source code as well as the original training data or representative substitute data are provided such that the presented approaches are reproducible to the highest possible degree. By gathering the best contributions of AI for geotechnics and engineering geology, this Special Issue will serve as a benchmark for many future developments in this field and further push the state of the art.

Guest editors: Franz Tschuchnigg, Georg H. Erharter, Thomas Marcher

More information can be found on the website of the SI.

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RMT Insitute Outing

Institute Outing Red Bull Ring in Spielberg

On a memorable day filled with excitement and adrenaline, our institute embarked on an exhilarating outing to the renowned Red Bull Ring in Spielberg, Austria. This action-packed adventure provided a unique opportunity to explore the world of motorsports while fostering team bonding and companionship among our members. The day commenced with a guided tour of the Red Bull Ring, a circuit known for hosting thrilling Formula 1 races. Led by knowledgeable guides, we delved into the rich history of the track and gained insights into the engineering marvels that make the Red Bull Ring a premier racing venue. From the intricacies of the track layout to the cutting-edge technology behind the safety systems, our tour immersed us in the fascinating world of motorsports. Next, we indulged in a box stop game, where we had the chance to simulate a tire change on a Formula 1 car. Divided into teams, we faced the challenge of working together, displaying precision and coordination as we swapped tires under the clock. This engaging activity not only tested our teamwork skills but also provided a glimpse into the high-pressure environment faced by pit crews during real races.

After an insightful morning, we recharged our energy with a delicious lunch at the track's restaurant, accompanied by the sound of racing cars flying over the race circuit. As the day neared its climax, we eagerly took part in a thrilling time trial race with go-karts. Putting on our racing helmets and strapping into the nimble vehicles, we embraced the spirit of competition and put our driving skills to the test. The adrenaline rush as we navigated the twists and turns of the track, fighting for the fastest lap times, created an electrifying atmosphere of friendly rivalry and pure exhilaration.

The outing to the Red Bull Ring proved to be an unforgettable experience for all. Not only did it offer an exciting glimpse into the world of professional motorsports, but it also allowed us to strengthen the bonds within our institute.

Guests & Visits I

Thursday lecture series of the faculty given by Dipl.-Ing., EMBA (HSG) Bernd Raderbauer

We are delighted to share a recap of the recent guest lecture titled "Construction of a 1,000 Megawatt Pumped Storage Power Plant Linth-Limmern - High-Performance Logistics Concepts and Sustainable Materials Management." This captivating presentation provided valuable insights into the remarkable engineering accomplishments and innovative practices used in logistics and materials management for this ground-breaking project.

The lecture was delivered by Dipl.-Ing., EMBA (HSG) Bernd Raderbauer, a distinguished expert in energy and infrastructure development and member of the executive board of Marti Tunnel AG. Attendees were captivated by Mr. Raderbauer's profound knowledge and expertise, making it an engaging and informative session. Throughout the lecture, the intricacies of constructing a 1,000 Megawatt pumped storage power plant in the Swiss high mountains were illuminated. The project represents cutting-edge engineering techniques and sustainable principles, providing a blueprint for the future of energy infrastructure. The lecture emphasized two key aspects: high-performance logistics concepts and sustainable materials management. The logistical challenges inherent in constructing a complex power plant with a big cavern in a mountainous environment were highlighted and attendees gained insights into the meticulous planning required.

Overall the lecture provided a wealth of knowledge and inspiration for attendees, regardless of their background or expertise. Students, professionals, and individuals interested in energy infrastructure development and difficult construction practices found the session particularly insightful. Mr. Raderbauer's real-world examples and practical insights left a lasting impression on all those in attendance.

We encourage those who missed the guest lecture to stay tuned for upcoming events. These sessions offer exceptional opportunities to learn from industry experts and stay abreast of the latest advancements in civil engineering.

Guests & Visits II

Joint cross-university PhD seminar (BOKU Vienna)

On Wednesday, 26 April 2023, the first joint cross-university dissertation seminar entitled – Green Automated Tunneling - took place at the University of Natural Resources and Applied Life Sciences. Doctoral students of different institutes, including those of Prof. Bergmeister (Head of the Institute of Structural Engineering), Prof. Flora (Head of Arbeitsbereich Baumanagement, Baubetrieb und Tunnelbau) and Prof. Marcher came together to exchange and discuss their dissertation topics in an informal setting (Table). During the seminar, the PhD students had an opportunity to present their research and participate in useful discussions. The professors and fellow students actively participated in the discussions and provided feedback and input that enriched the students' work. The collaborative environment encouraged the identification of potential areas for future collaboration and joint efforts among the participants. After the productive afternoon, all participants were invited to continue the exchange of ideas at a traditional Viennese Heuriger. Over food and drink, participants had the opportunity to relax and make further contacts to build on the connections made during the seminar. Overall, the joint cross-university dissertation seminar brought together doctoral students and professors from different institutes, which facilitated the exchange of knowledge and encouraged potential collaborations. The event provided a supportive environment for students to present their research and receive valuable input, while promoting networking and social interaction among participants. This event will continue next year at our Technical University in Graz.

Presenter	Topic
Paul Unterlaß/Alla Sapronova	TBM sensor data – Datenanalyse und ML Techniken im maschinellen Tunnelbau
Thomas Geisler	Cavern Thermal Energy Storages (CTES)
Lukas Hausberger	Nachhaltigkeitsbewertung von Eisenbahninfrastrukturen - Analyse von ökologischen und ökonomischen Potentialen
Larissa Schneiderbauer	Von BIM zum Digitalen Zwilling – Ein Prozessmodell
Matthias Rigler	Numerische Modellierung Raisebohrer
Makrini Macha / Angeliki Kosta	Basalt – emissionlow reinforcement
Johannes Hron	Kreislaufwirtschaft + Ansätze CO_2- Speicherung

Guests & Visits III

Dr. Kazuo Sakai | Taisei Corporation

On May 19th, we had the pleasure of having Dr. Kazuo Sakai from Taisei Corporation in Japan visit us for a day in Graz. After showing him our facilities at RMT we delved into an overview of our main research topics. The presentation soon developed into a fruitful discussion, which resulted in an extensive insight and a Japanese point of view on our research activities. We concluded the day with a joint dinner featuring authentic Austrian cuisine. This provided an opportunity for more insights and anecdotes from tunnel engineering culture in Japan, highlighting the importance of balancing intellectual pursuits with cultural exploration and culinary experiences. Once he had returned home to Japan, Dr. Sakai even mailed us additional technical input on the problems we had discussed – thanks a lot Kazuo and see you soon!

Partnership with Taisei Corporation

RMT is excited to continue its partnership with Taisei Corporation (cf. RR 01/23), marking the start of a new project that is aiming to transform the nature of excavation work, enhancing efficiency, safety, and reducing accidents in the process.

Recently, Taisei has integrated advanced computerized operation systems into their equipment. These systems are capable of carrying out automated drilling based on predefined plans and record machine data throughout the operation. This data, coupled with in-situ measurements is the processed by machine learning technologies to improve construction safety and efficiency.

This project focuses on minimizing deviation from the tunnel design plan, a prevalent issue in tunnel construction that often leads to increased costs and extended construction time. This project make use of state-of-the-art machinery to collect essential site data, and will employ latest development in data science to provide comprehensive data analysis opportunities to optimize the construction process further. This project follows the success of previous initiative where machine learning techniques were successfully implemented. The new project will involve extensive data handling, including pre-processing, analysis, and development, training, and accuracy assessment of machine learning algorithms.

This initiative represents an important step in shaping the future of construction and excavation, introducing a new era of safety and efficiency to the field.
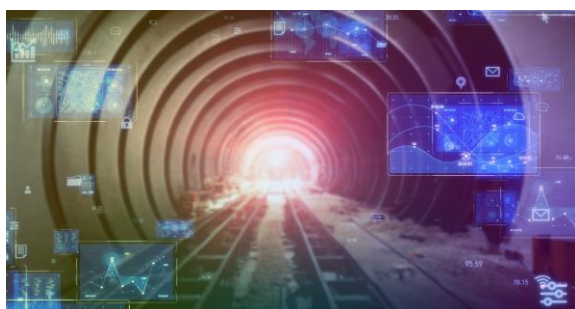
Teaching I

Résume of the 2nd "Applied Data Science for Geotechncis" lecture

During past June, the "Applied Data Science for Geotechnics" lecture was held for the second time as a regular lecture. Due to the welcoming large number of applicants, which exceeded the capacities of our lecture rooms, the lecture was held in a hybrid setting. About 32 students, ranging from undergraduate to graduate, took the chance to deepen their knowledge in the principal parts of data science and coding with Python, both with an applied focus on geotechnical engineering. The practical part of the lecture focused on applications of coding in Python, starting from the basics and progressing towards a sufficient level of proficiency for geotechnical analyses. The session was designed as an interactive lecture, incorporating practical examples and hands-on exercises. Students were encouraged to actively participate and engage with the material. During this portion of the lecture, fundamental Python concepts were covered, including data types, variables, loops, conditional statements, and functions. As the lecture progressed, more advanced topics such as file handling, data manipulation with libraries like NumPy and Pandas, and visualization techniques were explored.

The theory part of the lecture delved into the theoretical aspects of data science as applied to geotechnics. This segment aimed to provide students with a comprehensive understanding of the underlying principles of data science and its relevance to geotechnical engineering.

Topics covered during this theoretical portion included:
- Introduction to data management.
- Data pre-processing and cleaning techniques to ensure data quality and reliability.
- Data-driven modelling approaches for geotechnical analysis.
- Data engineering and transformation.
- Assessment and validation of results.

Theoretical concepts were explained using illustrative examples and case studies, helping students grasp the practical implications of data science in the context of geotechnical engineering. Overall, the lecture provided students with a holistic understanding of the subject matter. The combination of the practical coding exercises and the theoretical discussions on data science principles created a comprehensive learning experience. By the end of the lecture, students had acquired the necessary knowledge and skills to leverage Python for geotechnical analyses, as well as a solid foundation in the principles of data science in the geotechnical domain.
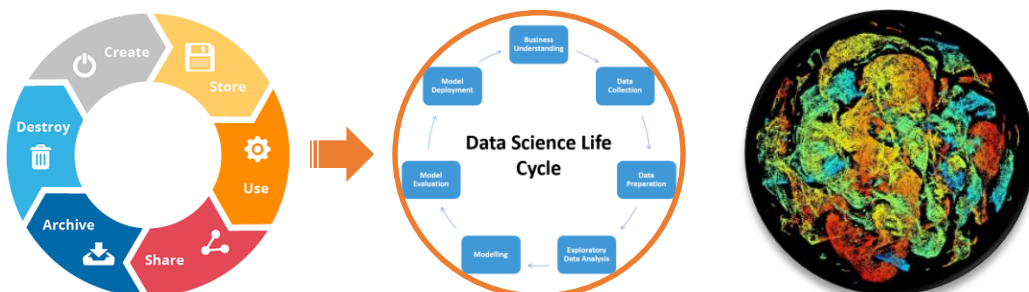
Teaching II

NATM Module 5 & Outlook Module 6

Regarding the NATM University program we have a lot to report as well. The recently concluded regular module, which ran from April to June, formed the fifth of the six modules carefully designed to provide students with the necessary expertise in NATM. As the students approach their upcoming graduation in September, the period between the fifth and the last module is of particular importance. During this phase, students have time to write their master's thesis, which they will work diligently on until they graduate in October 2023. What makes this collection of theses even more fascinating is the remarkable variety of topics chosen by the students from different fields, demonstrating their ability to engage with what they have learned and the issues associated with it. With an impressive international student body, the research topics explore and address challenges from all corners of the world, promoting a truly global perspective. So before module six starts, which will again take place in presence, students will finalize their theses and take their final exams, which will be the culmination of their entire academic journey. We are already looking forward to the exciting Master's theses!

Start of the 7th round:

After completion of round 6, the 7th round of the NATM University Course will start in September 2023. More information can be found on natm.at.

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Teaching III

Excursion Rock Mechanics and Tunnelling SS2023

Like every summer semester, our RMT-excursion took also place this year, taking us to Tyrol and Vorarlberg and further to Switzerland. On the first day we visited the Brenner Base Tunnel (BBT), a groundbreaking project that will become the longest tunnel in the world. The tunnel system, which connects Innsbruck (Austria) and Fortezza (Italy), will cover a distance of 64 kilometers, including the existing Innsbruck bypass. When completed, it will revolutionize the travel and transport system in Europe by reducing travel time from 80 to 25 minutes, relieving traffic congestion and promoting environmental sustainability. On the second day, we visited the Hagerbach test gallery, a renowned facility for research and development in tunnel construction, we were able to see numerous innovative projects. Located in the Glarus Alps, the tunnel serves as a training centre and research laboratory and attracts experts from all over the world. The tunnel offers a variety of experimental fields, including temperature influences in tunnels, building material analyses, underground construction and fire resistance of lining materials. Another highlight was the visit to the Illwerke Center Montafon in Vandans, where we toured the Lünersee II hydroelectric power plant and the Rodund I hydroelectric power plant. The Lünersee II project, the largest pumped storage power plant in Austria, has an impressive capacity of around 1000 megawatts. With an investment of around 2 billion euros, it is expected to generate electricity for 2.5 million households while having as little impact on the environment as possible due to its underground construction. All in all, these remarkable engineering achievements, which also include the BBT and the innovative projects of the Hagerbach Test Tunnel and the Illwerke Center Montafon, represent significant advances in the fields of tunnelling, renewable energy and sustainable infrastructure and offer promising solutions for future transport and energy needs.

A big thanks goes to the on-site excursion guides who made it possible for us to gain practical impressions!
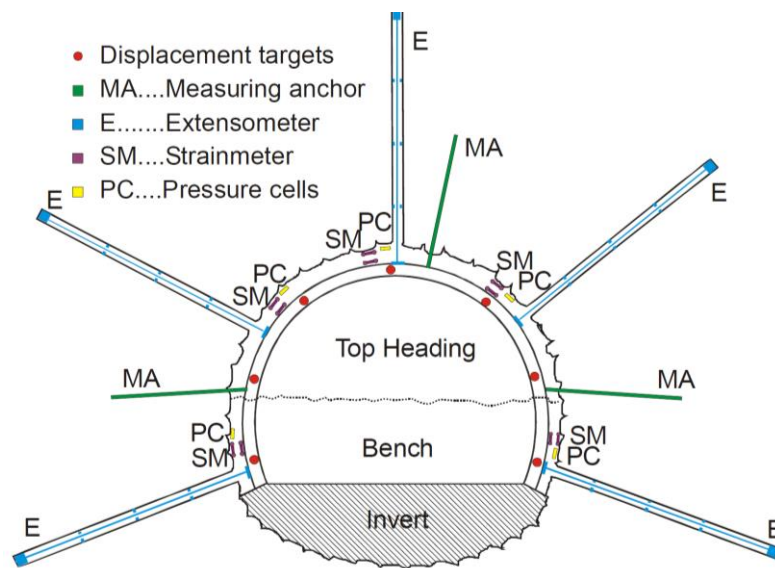
Teaching IV

Analysis of Sensor Data in Rock Mechanics and Tunnelling

This semester marked the launch of a newly introduced course. The course Monitoring Data Interpretation (NATM) was supplemented with further relevant topics and restructured. Alongside topics like displacement data interpretation, the course now includes comprehensive coverage of equipment, their sensors, and their programming-assisted evaluation. Therefore, the course is now referred to as "Analysis of Sensor Data in Rock Mechanics and Tunnelling"

Our master students attending the course on in this semester had the opportunity to hear a special lecture given by DI Johann Golser on "Sensortechnologies in Tunnels". As a well-known expert on geotechnical monitoring DI Golser serves as a member in several standardizing committees and he is founder, owner and managing director of the company GEODATA. This world-wide operating company is specialized on surveying in infrastructure, mining and industrial projects as well as providing tailor-made sensors, systems and software solutions at the state-of-the-art of science and technology to their clients. DI Golser shared his experience on geotechnical monitoring with the students and taught them focusing on practical applications as well as their theoretical fundaments. By bringing some of the most modern measurement tools from his company directly to our seminary room, he provided the students with an invaluable hands-on experience. Due to this manifold focuses time just flew by in this lecture and the feedback of the students was extraordinary positive. We are looking forward to allocate more time for this special lecture in the next semester's course.

Thank you Hans for giving our students the chance to learn from you!

Teaching V

Practical Seminar on Tunnel Construction and Geotechnics: A Hands-on Learning Experience

From June 27th to June 30th, 2023, our master's students participated in a practical seminar on tunnel construction and geotechnics at the "Zentrum am Berg (ZAB)" in Eisenerz (Austria), a real scale tunnel research facility led by Professor Robert Galler from the Montanuniversität Leoben (MUL). The seminar aimed to provide hands-on experience in various tasks associated with conventional tunneling, deepening the students' understanding of these processes and the effort involved.

The students independently performed tasks such as installing active and passive support systems, including SN-bolts, friction bolts, mechanical and self-drilling bolts, as well as wiremesh and lattice girders. Two simulator stations allowed them to practice drill-jumbo and shotcrete nozzle manipulation, which they later applied in real-world scenarios. Under supervision, each student manipulated the drilling booms of a genuine drill jumbo and performed manual shotcreting on an exposed rock face resulting from the blasting of a single tunnel round length. The program also included anchor tests to complement the comprehensive learning experience.

ZAB's realistic environment offered an immersive learning experience, providing our students with valuable insights. They witnessed the practical aspects of tunnel construction firsthand, enhancing their theoretical knowledge. Engaging in the tasks required for tunnel excavation deepened their appreciation for the field's complexity. The students gained an understanding of the challenges and efforts involved in executing various tasks related to conventional tunnelling, benefiting their future careers.

We express our sincere gratitude to Professor Robert Galler and the Montanuniversity of Leoben for making this valuable experience possible. We eagerly anticipate future collaborations and the potential for similar courses that provide practical training in tunnel construction and geotechnics.

Teaching VI

Recent master graduates at RMT - Abdallah Soliman & Matthias Hahn

Abdallah Soliman

On June 30, Mr. Abdallah Soliman, a student in the Master's program at Graz University of Technology, successfully defended his thesis titled "Information Extraction from Excavation Logs Data" under the supervision of Alla Sapronova. His research focused on optimizing blasting activities in conventional tunnelling by addressing the excavation of the tunnel cross-section. By utilizing Measurement While Drilling (MWD) data and employing machine learning algorithms, specifically random forest regression (RFR) and principal component analysis (PCA), Mr. Soliman developed accurate models for predicting the optimum volume of explosives. These models showcased accuracies up to 93.48% when utilizing MWD parameters and principal components as inputs. His research has significant implications for geotechnics, improving tunnel construction processes, and opening avenues for further exploration in this field.
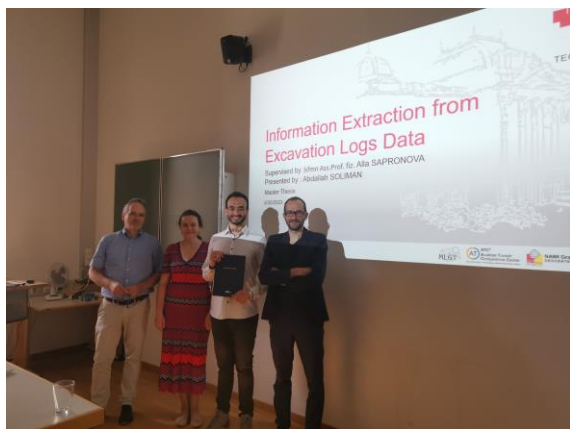
Mathias Hahn

In March 2023, Mr. Matthias Hahn, a master student at Graz University of Technology and Leoben University, successfully defended his master's thesis titled "Metrics in Machine Learning: A Quantitative Assessment of Dataset Performance." Under the supervision of Alla Sapronova and Marlene Villeneuve, Mr. Hahn's research focused on assessing metrics for monitoring the performance of machine learning models in geoengineering.

The thesis emphasized the importance of selecting appropriate evaluation metrics for different types of machine learning tasks, such as classification and regression. Mr. Hahn applied machine learning techniques to geoengineering data, employing specialized preprocessing techniques and training models. The evaluation of model outputs using comprehensive metrics was a significant aspect of his research.

The successful defense of his thesis highlights Mr. Hahn's dedication and the potential impact of his research on the application of machine learning in geoengineering. His work sets the stage for further exploration in this field, and the results can be reliably utilized in future projects.

Faces

… today's with our Secretary and a student of the Institute of Rock Mechanics and Tunnelling

Silvia Obermayr

I have been associated with the Institute's secretariat for 25 years, 14 of which I have been actively involved. I started in 1998 under Prof. Schubert, and after a break for children I started again in 2018. I have always seen it as my task to keep the operation running and, apart from organizational matters, I consider the solution of all possible problems to be my main activity. As a mother of two school-age children, I'm used to that. A positive aspect of my work is the fact that over the years, there have been a number of international staff and guests at the institute, which always provides variety and new challenges.I see myself as an integral part of the institute and never fail to mention that I work underground - in tunnelling. The balance to these two jobs for me is sport: swimming, tennis or yoga - the main thing is that I'm on the move to stay in the flow.

Rudolf Ginner (student)

My name is Rudolf Ginner and I have started my bachelor's degree in the year of 2018 at the University in Innsbruck. Because I have always worked alongside of studying, I was able to put my knowledge directly into the practical part at my job. During this time I knew that I wanted to learn even more and now I am just before graduation of the master's degrees, also in Innsbruck. I have the possibility to complete my master thesis together with the TU Graz, which pleases me very much. The reason for choosing the subject of tunnel construction was influenced by my university's subject of rock and tunnel mechanic which was one of the most fascinating subjects I had on my timetable. My thesis is based on the project the Kramertunnel in Garmisch-Partenkirchen, where the main topic is the stability of the tunnel face in the cohesionless soil. In this master thesis I will be using different analytical and numerical model approaches, in order to prove the stability of the tunnel face. Because the problem is three-dimensional, i have used the software Plaxis 3D to work on each tunnel driving layer and other supporting measures separately. Now am looking forward to finish my master thesis before starting a new chapter at the company BeMo Tunnelling GmbH.

Diary of Events I

> ATC²-Symposium 2023 RMT followed by "Barbarafeier"
Graz, Austria (2023/12/01)

Symposium by the Austrian platform ATC² (Austrian Tunnel Competence Center), a collaboration of Graz University of Technology and Montanuniversität Leoben. The aim of the symposium is to transfer innovative ideas and know-how in tunnelling. In English. The topics of the upcoming events are: Shallow Tunnelling, Urban Tunnelling incl. Metro Tunnels and Stations. Further information can be found on the ATC² homepage and on the subsequent page.
After the ATC²-Symposium our yearly "Barbarafeier" will take place.

If you are interested in sponsoring or advertising opportunities at both events, please get in contact with Ms. Ines Metzler MSc (metzler@tugraz.at). Regular updates are published via the event's homepage: http://austrian-tunnel-competence-center.at

> Thursday lecture series by Anne Merete Gilje
Graz, Austria (2023/12/14, 17:15 CET)

Lecture entitled "E39 Rogfast – The world`s longest and deepest sub sea road tunnel. It will be built in Rogaland Norway in the time window 2021 – 2033 with the Norwegian Method of Tunnelling (NMT)" by Anne Merete Giljem, an assistant project manager of the NPRA. The lecture will be in English and will take place in the lecture Room HS L (Lessingstraße 25/1, 8010 Graz). Registration via email addressed to tunnel@tugraz.at .
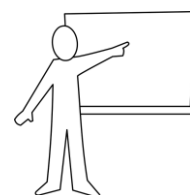
> 1st international Rock Mass Classification Conference (RMCC)
Oslo, Norway (2024/10/30&31)

The RMCC will provide an arena for international rock mechanics experts from academia and practice. The conference stands under the paradigm "Rock Mass Classification meets the Challenges of the 21st Century" and will be organized by the Norwegian Geotechnical Institute. RMT's Georg Erharter will be chairman at the conference and Prof. T. Marcher has joined the scientific committee.

Save the date!

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

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

Symposium by the Austrian platform ATC² (Austrian Tunnel Competence Center), a collaboration of Graz University of Technology and Montanuniversität Leoben. The aim of the symposium is to transfer innovative ideas and know-how in tunnelling. In English. In 2024, ATC² will be hosted at the guest location in the City of Innsbruck. Information on the topics of this event will follow. http://austrian-tunnel-competence-center.at

>"Barbarafeier" 2024
Graz, Austria (2024/11/29)
More information will follow. Save the date.

Diary of Events II

ATC² - "Shallow tunnels, subway construction"

ATC²
Austrian Tunnel
Competence Center

"Shallow tunnels, subway construction"

Pre-Announcement - Detailed programme to follow

December 1st, 2023

Graz University of Technology
Rechbauerstraße 12, 8010 Graz

Organizers

Univ.-Prof. Dipl.-Ing. Dr.-Ing. Thomas Marcher
Institute of Rock Mechanics and Tunnelling
Graz University of Technology

Univ.-Prof. Dipl.-Ing. Dr.mont. Robert Galler
Chair of Subsurface Engineering
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Following the symposium, we would like to cordially invite you to our annual Barbarafeier taking place in the same premises.

Authors

Focus Project S-LINK, Salzburg

- Greinmeister, A. (S-LINK, Salzburger Regionalstadtbahn Projektgesellschaft)
- Saurer, E. (Skava Consulting); Greinmeister, A. (S-LINK)
- Jedlitschka, G. (Geoconsult); Kohlböck B. (IGT); Eder, M. (Laabmayr); Greinmeister, A. (S-LINK)

Focus Tunnelling Specifics of Metro/Subways

- Schweiger, H. (Wiener Linien); Wäger, R. (Strabag) - Line Intersection U2xU5, Vienna
- Massimo-Kaiser, I.; Salzgeber, H.; Flora, M. (University of Innsbruck) - Model-based prediction reliability
- Classen, J. (Implenia); Listl, R. (DB Netz) - Marienhof Station, Munich

Focus International Projects

- Larsson-Gruber, B. (Trafikverket) - Metro Station Odenplan, Stockholm
- Raja, S. U.; Landergren, H.; Thurner, R. (Keller Grundläggning) - WestLink project, Gothenburg
- Cavagnet, S.; Mancinelli, L.; Midali, E.; Diallo, I. (Lombardi) - Grand Paris Express
- Lagger, H. (ARUP); Sainsbury, D. (Geotechnica); Sainsbury, B.-A. (Deakin Uni); Storry, R. (Bouygues) - Melbourne MetroTunnel
- Toledo, M.; Cárcamo, V.; Silva, D. (Skava Consulting SA) - Metro Review AVO II, Santiago de Chile

Advertising opportunities

Description	Cost per unit*
Poster [1)2)]	€ 250,-
Roll-Up [1)2)]	€ 300,-
Advertising material as an insert in the conference bag [2)]	€ 360,-
Company logo on conference bag	€ 600,-
Banner in the lecture hall [2)]	€ 900,-

* excl. any taxes and advertising fees
[1)] Information on possible positions in the event area on request
[2)] Information on possible dimensions on request

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The contributions to the ATC² will be printed in issue 6/23 of the Geomechanics and Tunnelling and will readily distributed at the STUVA Conference in November 2023, Munich.

# Have a look at our Master's Theses I

The institute has different research areas and offers numerous topics for a master thesis.
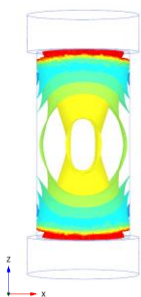
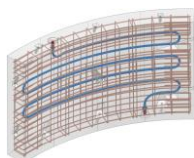- **Numerical and experimental investigation of rock anisotropy**

(supervisors: T. Frühwirt, M. Winkler)

Rock is a complicated material, for example it is very often anisotropic making its' deformational and strength characteristics dependent on the loading direction. To learn more about this phenomenon, numerical and experimental studies need to be carried out.
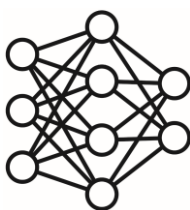
- **Machine Learning (supervisor: G. Erharter, P. Unterlass)**

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

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

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.

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

- **Characterization and Modeling of Hard Soil/Soft Rock considering Anisotropy and Swelling Capacity (supervisor: I. Metzler)**

The ChaMod-HSSR project (cf. Rock Report 03/3) aims at an extensive characterization of transitional material excavated with the construction of the Angath adit in Tyrol, Austria. The local Unterangerberg formation comprises hard soil/soft rock (HSSR) with strong anisotropic tendencies as well as a certain swelling capacity due to the clay minerals present within the rock mass. To achieve a comprehensive rock mass characterization, the project objectives are the creation of a reliable and precise database of geological and geotechnical parameters to be achieved via in-situ and laboratory tests, and are to be implemented in numerical models in the third step. The latter aim at predicting relevant, possibly extraordinary material behavior on both, small- and large-scale models. Master's theses may be assigned for selected parts of the project depending on the student's interests as well as the current project and construction progress.

Have a look at our Master's Theses II

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

Advances in engineering equipment that is now capable to delivers massive in-situ data at runtime, open the possibility of employing data analysis and data-driven modeling to ensure proactive risk management and optimize the work. Although a large number of features characterize the geotechnical data, its extreme volumes and sparsity place special constraints on the applications of the data science methods in geoengineering and the special focus shall be placed on the data quality assessment, pre-processing routines, and integration of the data from various sources.

- **Digital Face (supervisor: A. Sapronova)**
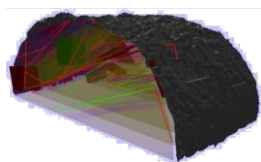
Various data near and at the tunnel face is available during the underground construction: from hand-made technical sketches made by geologists to the 3D point-cloud datasets from seismic surveys. Integration of such information into a harmonized database that will help to forecast the geological conditions and ensure safe tunneling. Ongoing research aims to find methods for the information extraction and integration to move further from the survey data to the dynamically updated visual and digital representation of a tunnel face.

- **Aspects of steel – rock contacts in TBM tunneling (supervisor: G. Erharter)**

New contractual developments set a focus on the effect of shield friction in hardrock TBM tunneling. Low speed and low stress contacts between steel and rock have not been explored a lot so far and the goal of this study is to focus on geometrical and mineralogical aspects of contact points between tunnel boring machine (TBM) shields and the tunnel wall. Research questions that need to be answered are for example: What are the contact points between a TBM shield and the tunnel wall in slanting and curved driving conditions? Which mode of TBM driving is most unfavorable in terms of expected frictional resistance? Are there correlations to standard abrasivity tests such as the Cerchar abrasivity? Methodologically the thesis should contain theoretical work, analog models, and geotechnical laboratory work (abrasivity tests). The master thesis is part of a currently ongoing bigge rresearch endeavor on this matter.

Have a look at our Master's Theses III

- **Application of an existing testing device to check successful pea-gravel bedding of segmental linings** (supervisor: **T. Marcher**)

The goal of the thesis is to apply an existing testing device (prototype) to real conditions at the construction site. The thesis shall focus on the application limits and optimization proposals for a regular use during the segmental lining installation. The involved company offers a position as a trainee and practice-oriented supervision.

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

How many exploratory boreholes are necessary in the course of long, deep seated (base-)tunnels? Which insitu and laboratory tests are carried out as standard? How are the explorations distributed between the different project phases? The work focuses on the collection of data based on the experience gained in the construction of deep-seated tunnels in the Alpine region. The data will be systematically analyzed and the results of the different tunnel constructions will be compared.

- **A case study: Cavern Stability Analysis (supervisor: T. Marcher)**
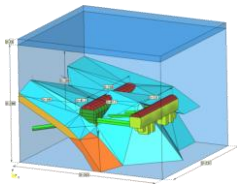
In the course of excavating a cavern, difficult tunnelling conditions were encountered in an executed project. The aim of the thesis is to numerically backcalculate the observed behaviour. The involved company offers a position as a trainee and practice-oriented supervision.

- **Definition of discontinuities in case of foliated rock (foliation)** (supervisor: **T. Marcher**)

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

- **A case study: back-calculation of shallow tunnel highly sensitive to surface settlements in urban environment (supervisor: T. Marcher)**
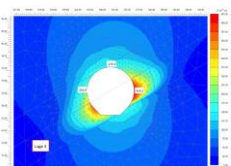
Numerical study. The tunnel has been excavated with side drifts (Ulmenstollen). The focus of the work is on the prediction of the tunnel stability and surface settlements. Numerical analysis shall be performed of which settlements can be expected if a different excavation concept is chosen. The surrounding ground consists of sand. The influence of improving the ground prior to excavation shall be considered as well..

Positions at RMT
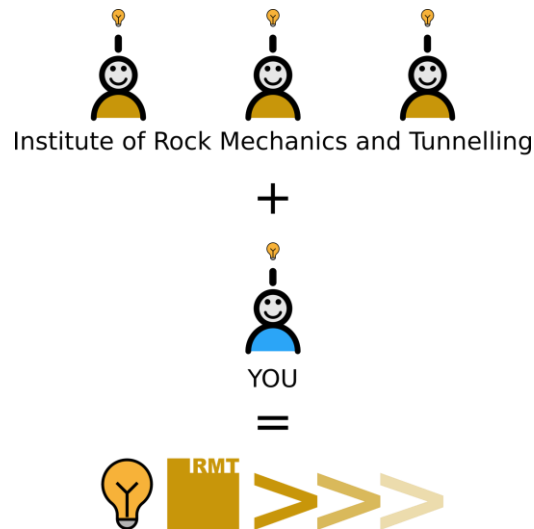
Open Positions

- We are looking for a technician to support our laboratory team. The job offers plenty of variety as it includes diverse tasks ranging from operating high-end measuring equipment to skilled manual work such as drilling and sawing of rock cores. This challenging full-time job may be started as soon as possible. For more information just send us your contact details via tunnel@tugraz.at.

JOIN RMT – we'd love to welcome you.

Cooperation

… please contact us in case we forgot you here

... moving forward

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