Master programme in Geoengineering

Study path “Rock Engineering”

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28.8.2024

Aalto University
School of Engineering

WHAT IS ROCK ENGINEERING? WHERE NEEDED?

Contents

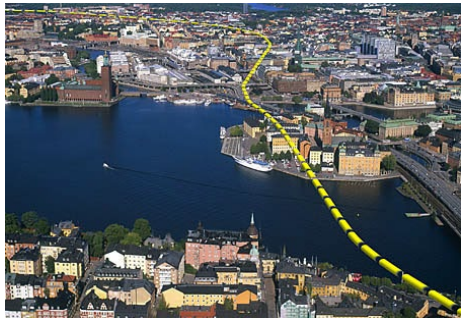
- Rock engineering
- Rock engineering study path
- Study and research and facilities

Mikael Rinne

- 1988 DI (MSc), Aalto Univ. (TKK)
- 1987-2008 Consulting and research (Companies in Finland and Sweden)
- 1996-2000 PhD studies at KTH, Sweden
- 2006 – 2008 PhD studies at TKK/Aalto, Finland
- 2008 - professor at TKK/ Aalto Univ.

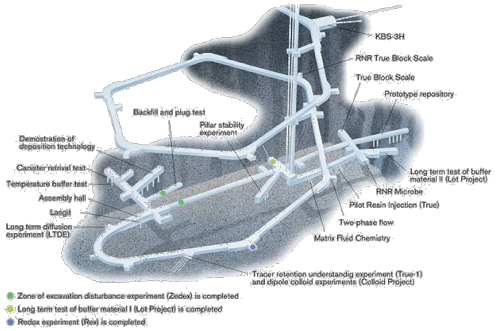
Preliminary planning of E18 Muurla-Lohjanharju tunnels (1991-1993)

Auditing design of Citybanan railway under Stockholm (2005-2007)

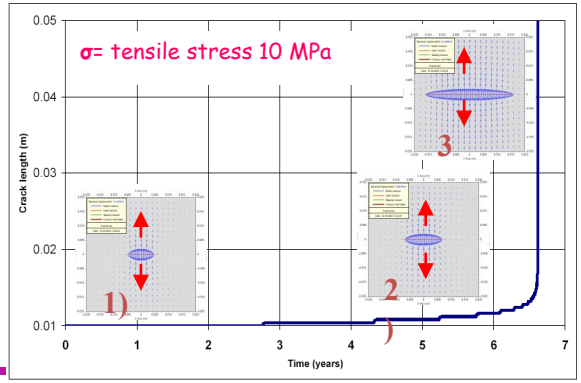


Auditing Angouran zink mine, Iran (2001)

Research for design of radioactive waste disposal, Sweden and Finland (1997-2008)



Doctoral thesis “Time dependent failure model of rock” (2004-2008)



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Rock Engineering, where needed?

- Civil Engineering: traffic tunnels, underground facilities and storages etc
- Mining: metal ores, industrial minerals, quarries

Tunnelling

Dimensional stone industry

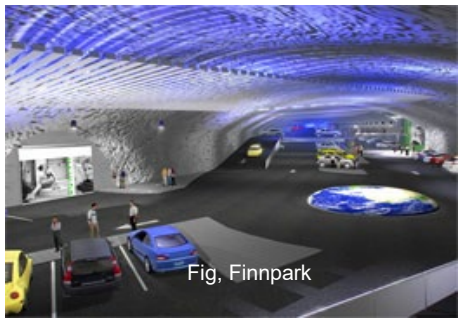
Mining

Aggregates

Mining machine manufacturers

Underground facilities for varying purposes

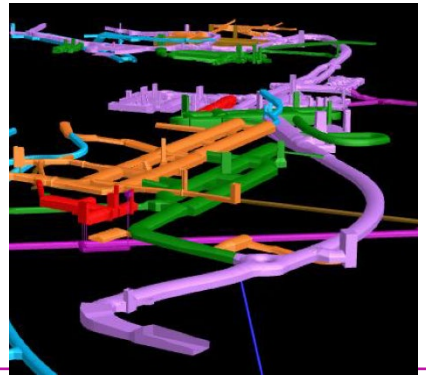
- **Traffic and parking**
- **Civil defence shelters**
- **Storage and equipment space**
- **Water distribution and wastewater treatment**
- **Power plants, district heating and cooling, energy storage**
- **Sport facilities**
- **Tourism and restaurants**


Fig, Finnpark

HELSINKI

- More than 400 underground spaces and tunnels
- Underground master plan due to increased underground construction
- More than 200 reservations for new underground projects

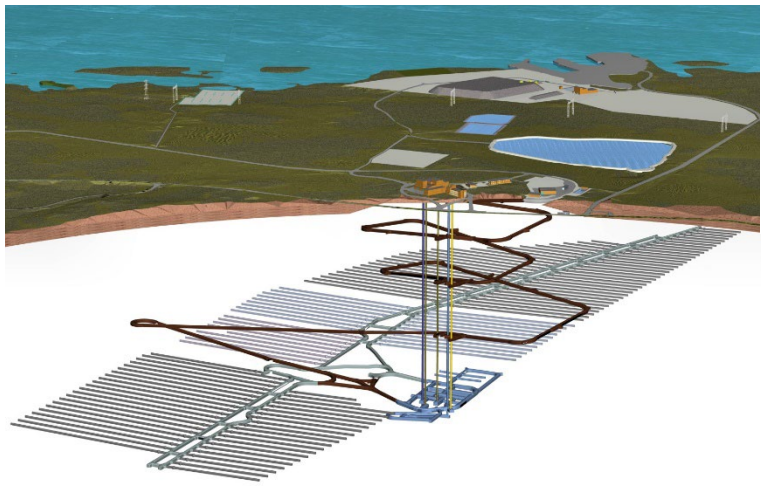

Fig. Rockplan



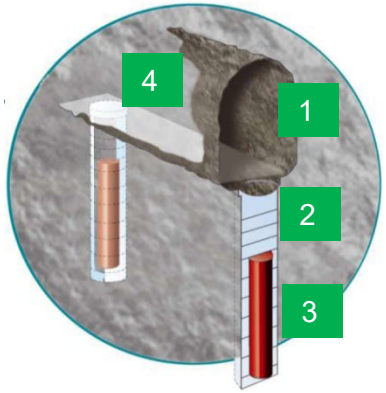
Underground facilities and space reservations in center of Helsinki. City of Helsinki,

Rock engineering projects

Underground disposal of spent nuclear fuel, Olkiluoto, Finland

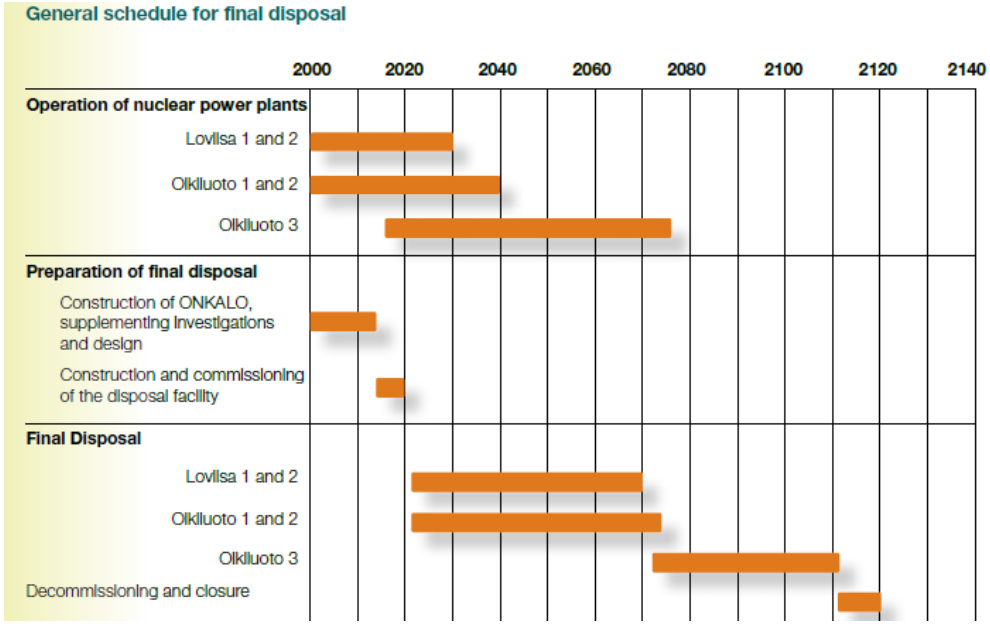


- Finland is most likely the first country to start final disposal of spent nuclear fuel (2025).
- The license application has been submitted to the Ministry of Employment and the Economy (DEC 2021)



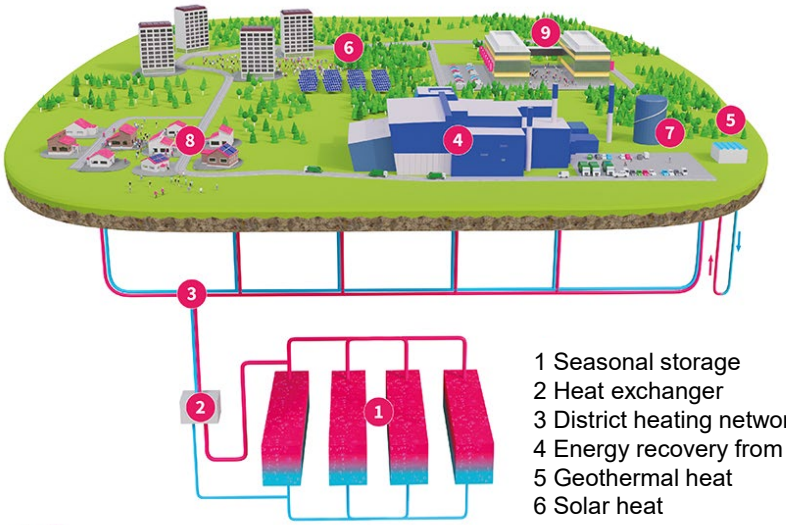
1. FINAL DISPOSAL TUNNEL
2. BENTONITE
3. METAL CANISTER
4. BACKFILL MATERIAL

Figures: www.posiva.fi



Rock engineering projects

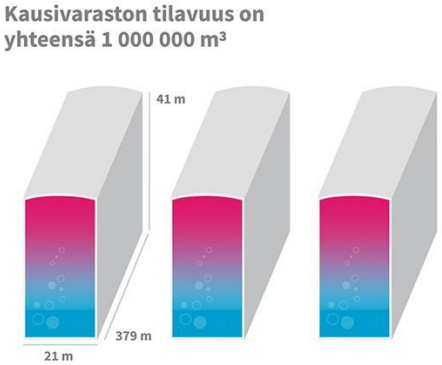
The world's largest seasonal heat storage planned to be built in Vantaa

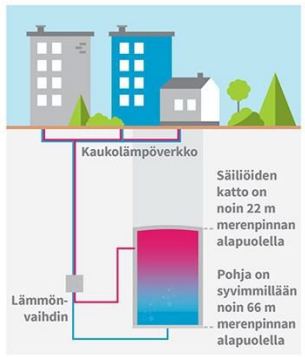


Vantaan Energia

1 Seasonal storage
2 Heat exchanger
3 District heating network
4 Energy recovery from waste
5 Geothermal heat
6 Solar heat
7 Heat accumulator
8 Combined cold and heat production
9 Waste heat recovery

- The operating principle of the seasonal heat storage is based on high water storage temperature of 140 degrees => high rock stress
- Volume ~ 1Mm^3
- Capacity 90 GWh / corresponding 65´000 t CO_2-equiv./year
- Scheduled to be commissioned in 2026.





https://www.vantaanenergia.fi/fossiiliton-2026/maailman-suurin-lammon-kausivarasto-vantaalle/
https://www.vantaanenergia.fi/lampoverkko-on-ilmastoystavallisen-energian-jakelukanava/

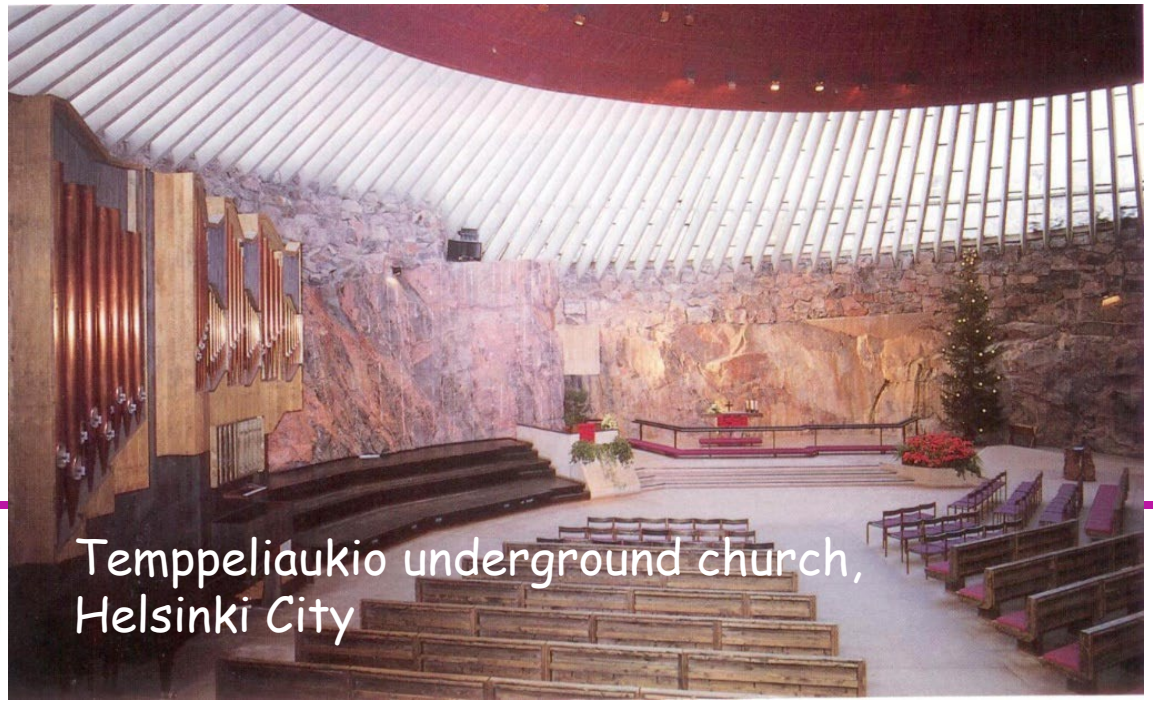
https://www.yit.fi/ytimessa/lammon-kausivarasto

Go and check Helsinki underground:

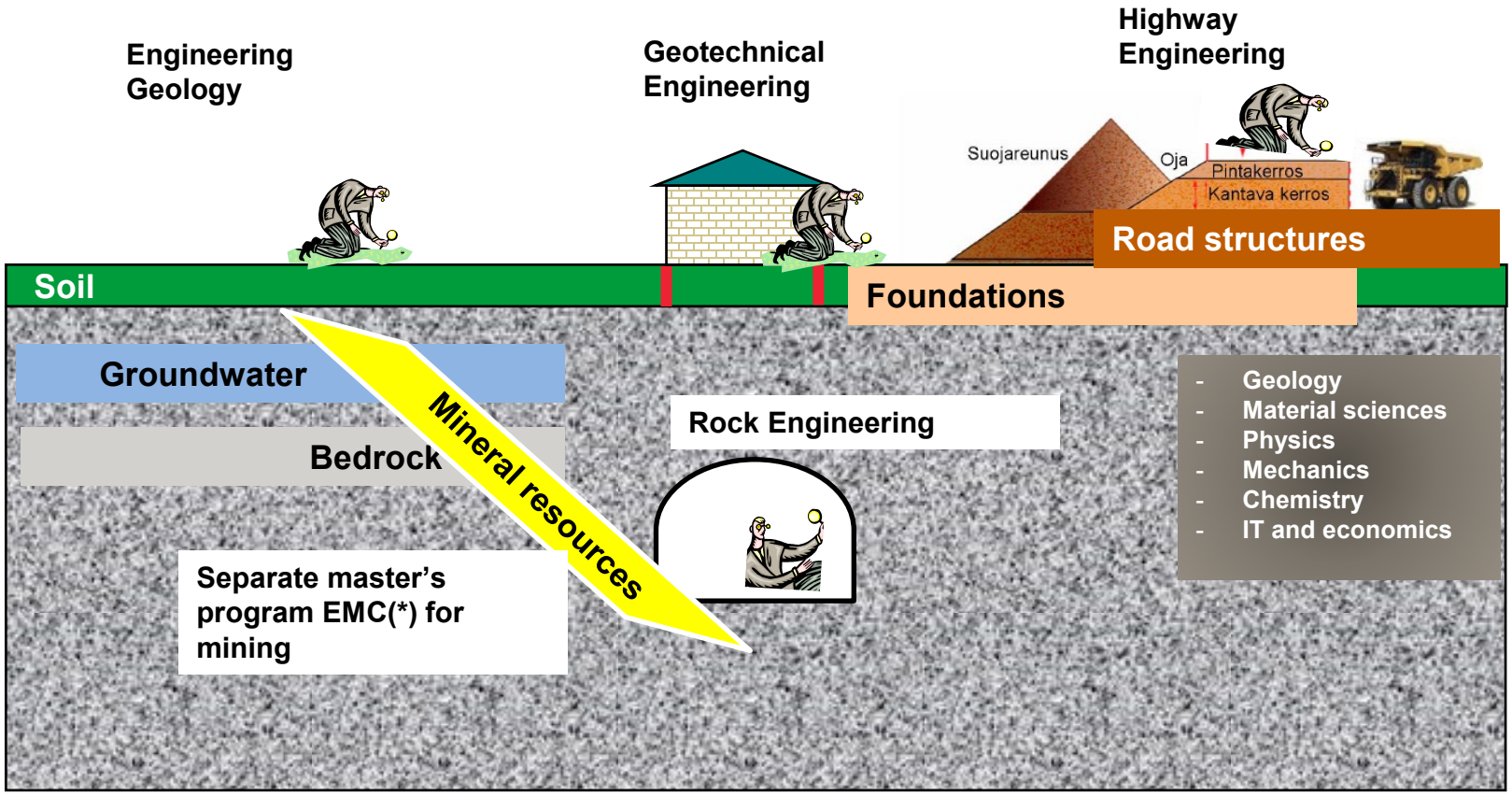
Helsinki Urban Underground Spaces - Guidelines for visitors
https://www.researchgate.net/publication/335790309_Helsinki_Urban_Underground_Spaces_-_Guidelines_for_visitors

CNN video Youtube: Europe's Underground City - Helsinki:
https://www.youtube.com/watch?v=munQwhSdUn8

The World of Underground Opportunities (mostly about Helsinki):
http://www.youtube.com/watch?v=fGILwarH18s


Temppeliaukio underground church, Helsinki City

Geoengineering at Aalto 2024 - study paths



(*) EMC- European Mining Course

Rock Engineering study path provides:

- Readiness to utilize bedrock as an underground space, mineral & energy resource.
- Proficiency in designing optimal structures in the rock and expertise to carry out these plans in a safe, economic and most environmentally friendly way.
- The core fields are rock mechanics, excavation techniques and applied geosciences.

Master's Programme in Geoengineering

Common courses (20 cr)

Obligatory courses (5 cr each)

- Engineering Geology
- Geotechnics
- Structural Design of Roads
- **Rock Excavation**

Elective studies (30 cr)

- Include also "Advanced courses"
- Exchange studies warmly recommended!

Master's thesis (30 cr)

- See instructions

Advanced courses (40 cr)

Student selects 8 courses (5 cr each)

- Advanced Soil Mechanics
- Bituminous Materials and Mixtures
- Design Process Management (CIV)
- Economic Geology and Mineral Economics
- Foundation Eng. and Ground Improvement
- Fundamentals of Structural Design (CIV)
- Geometric Design of Roads
- Numerical Methods in Geotechnics
- Project Course in Geoengineering
- Reinforced Concrete Structures (CIV)
- Road Maintenance and Rehabilitation
- **Rock Construction**
- **Rock Mechanics**
- Seminar in Geoengineering
- Special Assignment in Geoengineering
- Sustainability and Circular Economy in Civil Engineering

https://www.aalto.fi/en/programmes/masters-programme-in-geoengineering/curriculum-2024-2026
https://www.aalto.fi/en/programmes/masters-programme-in-geoengineering/thesis

Core Courses in Rock Engineering

Rock Excavation, 1st year period III. Common studies /Rinne

- Drilling, blasting and excavation methods for quarrying, tunneling and mining.
- Blasting and explosives
- Loading, hauling, dumping and crushing.
- Rock reinforcement, grouting, ventilation and dewatering.

Rock Mechanics, 2nd year, period I. Advance studies / Rinne

- Rock and rock mass as material
- Rock stress and its measurements
- Failure mechanisms
- Laboratory and field testing of rock properties

Rock Construction 1st year, period V. Advance studies / Siren

- Planning and special requirements for the typical rock facilities
- Special solutions for excavation and reinforcement
- Rock reinforcement design concept for underground spaces and mining.
- Monitoring of rock structures.
- Environmental impact of excavation.
- Legislation related to rock construction.

Professor of Practise
Topias Siren

Course suggestions for the study tracks "Rock Engineering"

ADVANCED STUDIES 30 cr	Rock Engineering		
V= Very Important, S=suggested, A=Additional	V	S	A
• Foundation Engineering and Ground Improvement	x		
• Advanced Soil Mechanics		x	
• Numerical Methods in Geotechnics	(x)	x	
• Rock Mechanics	x		
• Economic Geology and Mineral Economics		x	
• Rock Construction	x		
• Bituminous Materials and Mixtures			x
• Geometric Design of Roads		x	
• Road Maintenance and Rehabilitation		x	
• Seminar in Geoengineering			x
• Special Assignment in Geoengineering			x
• Project Course in Geoengineering	x		
• Fundamentals of Structural Design (CIV)	(x)	x	
• Reinforced Concrete Structures (CIV)	(x)	x	

30.8.2022

Electives for study path “Rock Engineering”

- Interested in material resources? Take **Mineral Resource Engineering (minor)**
- Interested in design of rock structures? Introduce yourself in **FISE Certifications!** Especially for “Designer of rock structures” (kalliorakenteiden suunnittelijan pätevyys) and for “Site managers of rock works” (kalliorakenteiden työnjohtaja) **http://fise.fi/en/**
- Some courses to be considered depending on the field of interest:

• Mechanics of Beam and Frame Structures (CIV)
• Construction Management (CIV)
• Operations management in Construction (CIV)
• Environmental Risk Analysis (WAT)
• Sustainability in environmental eng. (WAT)
• Circular economy in environmental engineering (WAT)
• Transport System Planning (SPT)

Elective studies (30 cr)

Mineral Resource Engineering

https://www.aalto.fi/en/minors/mineral-resource-engineering-minor

Select 5 courses, total of 25 cr.

ENG-Courses

- GEO-E1040 Rock Excavation, (III).*.
- GEO-E1010 Engineering Geology, (IV).*
- GEO-E3010 Economic Geology & Mineral Economics, (II).
- GEO-E2030 Rock Mechanics, (I).

CHEM-courses

- CHEM-E6140 Fundamentals of Minerals Engineering and Recycling, (I). **
- CHEM-E6130 Metal Recycling Technologies, (II). **
- CHEM-E6145 Unit Operations in Mineral Processing and Recycling, (III-IV) (pre-requisite CHEM-E6140)
- CHEM-E6235 Circular Economy for Materials Processing, (IV-V).
- CHEM-E6215 Circular Economy Design Forum, (IV).

(*) Student studying the MSc programme Geoengineering cannot include this course in the Minor (already a mandatory course).
(**) Student with the major in Sustainable Metals Processing can not include this course in the Minor.
Each course 5 cr.

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Research

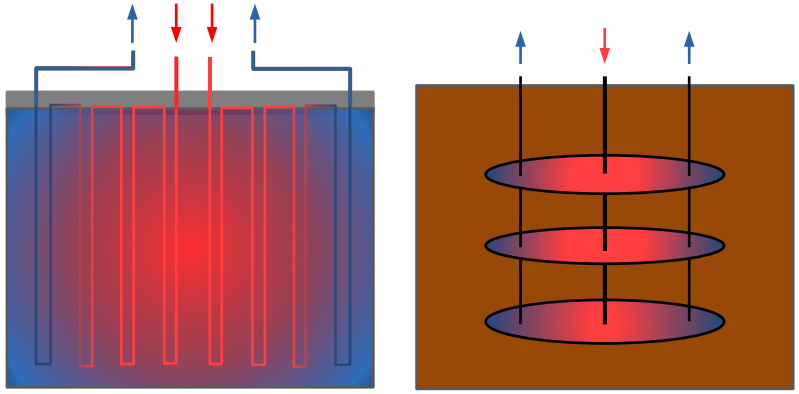
Research tunnel for exercises

- **Drilling, bolting, hauling & loading exercises**
- **Exercises in geological and geophysical investigations**

Modelling

Software:
- FLAC 2D/3D
- UDEC, 3DEC
- PHASE 2, EXAMINE
- FRACOD2D
- UNWEDGE, SWEDGE,SLIDE,DIPS
- COMSOL

Heat storages in rock
Fig. Janiszewski 2019

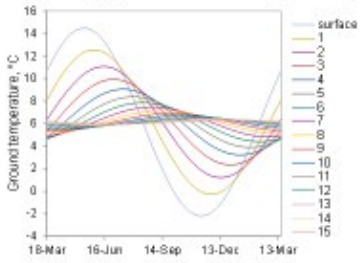


Model set-up

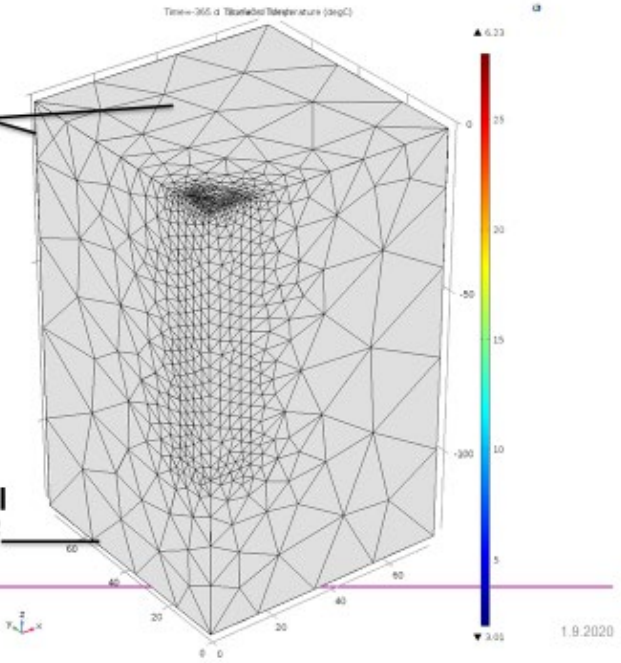
Ground temperature

$$T_{z,0} = 0.71 \cdot T_{air} + 2.93$$

$$T(z) = T_{z,0} + \Delta T \cdot e^{-A} \cdot cos(\omega t - A)$$

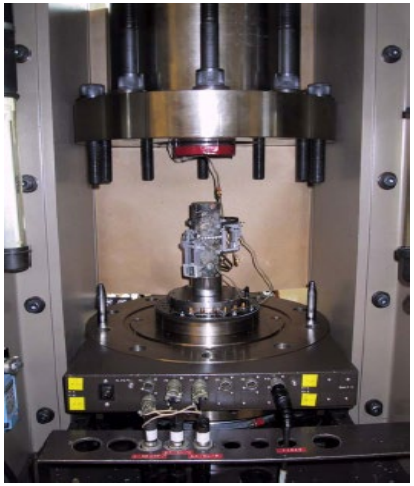


Arithmetic mean of **geothermal heat flux** in Finland **37 mW/m^2**
(Kukkonen, 2000)



Rock laboratory
- testing and research

Pressure apparatus
MTS 815
for material testing



- Strength and deformation properties of rock, backfill, concrete etc.
  - Nuclear waste disposal
  - Tunnelling projects
  - Mine projects
- Drillability properties of rock
- Frictional properties of rock joints
- Point load strength of rock
- Tilt table device etc

Recent and ongoing doctoral studies

- **On-line monitoring and risk management in deep mining (Mishra)**
- **Seasonal underground storage of solar thermal energy in hard crystalline rocks (Janiszewski)**
- **Dust distribution from open-pits (Sitkiä)**
- **Geophysical and Geochemical methods for stope design (GAGS, Kiuru)**
  Prediction of geotechnical and geochemical conditions for safe and profitable operations.
- **Mechanical Properties of Rock Joints –KARMO / RAKKA (Uotinen, Torkan)**
  Photogrammetry and 3D printing technology to study scale-dependency of fracture surface properties and hydro-mechanical properties

What is topical for the industry?

RECENT MASTER'S THESIS PROJECTS

MSc thesis: Rock mech and design

- Characterization of hydromechanical properties of rock fracture using numerical modeling with comparison to steady state flow test
- A Multi-criteria decision-making comparative study for subsurface hydrogen storage
- Influence of mine planning and design on the hydroelectric potential in the Peruvian Mining industry
- Geotechnical and functional boundaries for design of an underground wastewater treatment plant
- Differences in grouting practices between Finland and Sweden
- Interpretation of displacement data from the West Metro project
- Development and testing of smart rock bolt for rock stress monitoring
- Impact of thermal background stresses on the rock reinforcement of a nuclear waste repository
- Utilization of drilling data in a tunnel project
- Development of the tunnel data in the Tunnel Register

MSc thesis: Energy and environment

- The impact of design on the carbon footprint of the rock construction project
- Use of micro-fibrillated cellulose as additive for wet-mix shotcrete formulation
- A Multi-criteria decision-making comparative study for subsurface hydrogen storage
- Influence of mine planning and design on the hydroelectric potential in the Peruvian Mining industry
- The carbon footprint of a rock construction project
- Resource-based estimating model of tunnel construction phases

MSc thesis: Mining

- Development of methodology to provide stability analysis of a highwall using drone acquisition data
- Battery metals extracting potential and environmental impact of graphite mine tailings
- Stress-testing climate risk on copper mining
- Quantification of deformation trends in a sublevel caving mine using mobile 3D laser scanning
- The development of an evaluation tool to compare the visual impact of opencast mining operations in the pre-feasibility phase
- Finite difference method in assessment of suitable mining method in Kemi mine
- Evaluation of stability for different stoping sequences through the use of numerical modelling
- Identification and impact assessment of parameters on open stoping in the Kylylahti mine

MSc thesis: Mining machines

- A digital model to predict the real-world production of shovels
- Utilization of drilling data in a tunnel project
- Industrial Internet of Things implementation of a discontinuous extraction process from loading to dumping on the example of a diabase quarry

Master thesis projects: Blasting

- Improving efficiency and adding value in charging bulk explosives in sublevel stoping using novel technologies
- Mining vibration amplitude study to assess excavation damage
- Effect of shock wave collision on blast induced vibrations in hard rock
- Effects of pressure shock and vibrations on unfinished reinforcement structures in a railway tunnel
- The effect of geometrical presplit blast parameters on presplit quality at Kuusilampi open pit mine
- Comparison of the blast performance of Ammonium Nitrate/Fuel Oil and emulsion explosives with emphasis on the production of blast fumes in underground salt mining conditions
- Development of an Explosive Energy Distribution Optimization System to accommodate drilling errors by adjusting blasthole charges
- Effect of charge column's velocity of detonation and location of initiation on blast induced vibration's frequency in rock mass

Thanks and Welcome!

Photo by Tuuli Sotamaa
Aalto University