Geotechnical Engineering

Wojciech Sołowski
Geoengineering Programme Leader
27th August 2024

Aalto University
School of Engineering

	Tuesday 27th August 2023, R5	Wednesday 28th August 2023, R266
8.30-10:00	Chairman: Sanandam Bordoloi 8.30 **Welcome!** Introduction to Geoengineering Master Programme (Wojtek Sołowski) and presentation of the students **Study paths, courses and teaching / research infrastructure:** 9.20 Geotechnical Engineerring (Wojtek Sołowski, Sanandam Bordoloi) 10.00 Highway Engineering (Yuxuan Sun) 10.30 Engineering Geology (Jussi Leveinen) 11.00 Photo session (Otto Hedström, Lauri Uotinen)	Chairman: Sanandam Bordoloi 8.45 - 9.15 Rock Mechanics (Mikael Rinne) 9.15 - 10.30 All Well! (Sanni Saarimäki) 10.30 - 10.45 Geotechnical and Rock Engineers' club presentation (Otso Laurila, Juuso Eskelin) 10.45 - 11.15 Introduction to study services (Minna Marin) **11.15 - 11.30 Selection of study advisor**
10:00 - 11:30		
11:30-12:00	Lunch break	Lunch break
12:00-13:00		
13:00-14:00	**Tunnel and laboratories tour (Otto Hedström, Veli-Antti Hakala)** ~13.00 Geotechnical Laboratory (Alejandra Lopez-Ramirez) ~13.25 General laboratory, testing hall afterwards Highway laboratory afterwards Research tunnel	Chairman: Sanandam Bordoloi **Presentations from industry (13.00-16.00)** 13.00 - 13.25 Destia (Miia Paatsema, Kaisla Kivistö) 13.25 - 13.50 Ramboll (Piitu Kurtilla) 13.50 - 14.15 WSP (Emilia Köylijärvi?) 14.15 - 14.40 AFRY (Samu Portaankorva) 14.40 - 15.05 A-Insinöörit (Hamilkar Alava Bergroth) 15.05 - 15.30 Sitowise (Nina Tanskanen, Iikka Kronkvist) 15.30 - 15.55 SWECO (Juho Rahko) 15.55 - 16.00 Closure (Sanandam Bordoloi)
14:00-15:00		

A?

About me?

Wojtek Sołowski

Geotechnical Engineering

- Numerical Methods
- Soil Modelling
- Director of the MSc programme
- International Secretary of Finnish Geotechnical Society
- Member of Eurocode committee
- Member of TC 106, unsaturated soils, ERTC7 numerical methods and numerical methods in EC7

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MSc:Politechnika Śląska, Gliwice, Poland

PhD: Durham University, Durham, UK 2005 - 2008

Research Associate: University of Newcastle, Australia 2009 - 2014

2014 onwards Aalto University, now Associate Professor (tenured)

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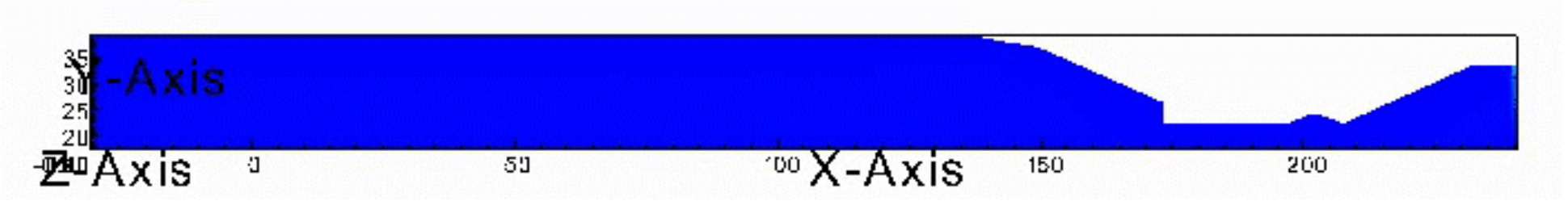
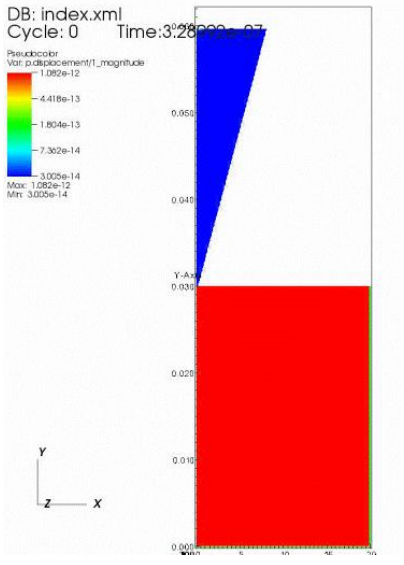
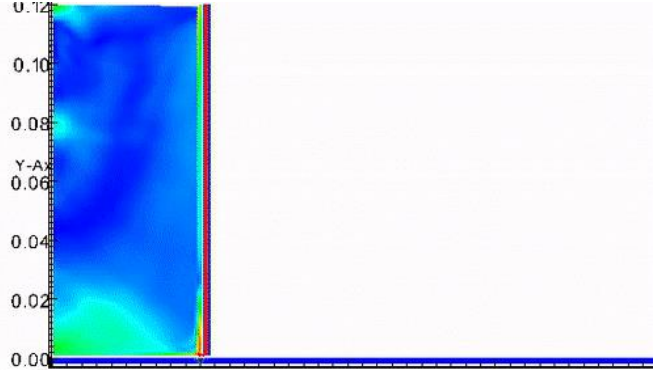
Landslides and large deformations analyses



St. Monique Landslide simulation

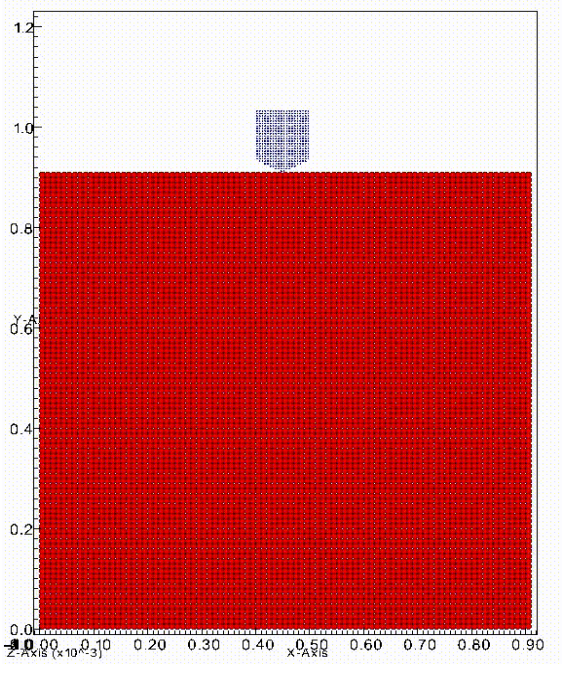


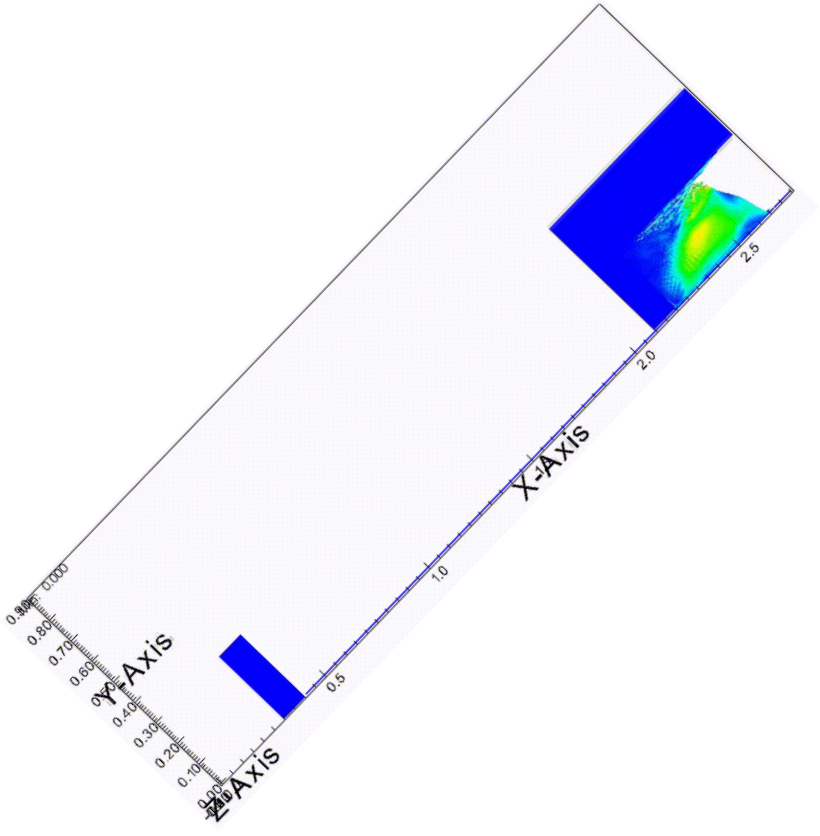


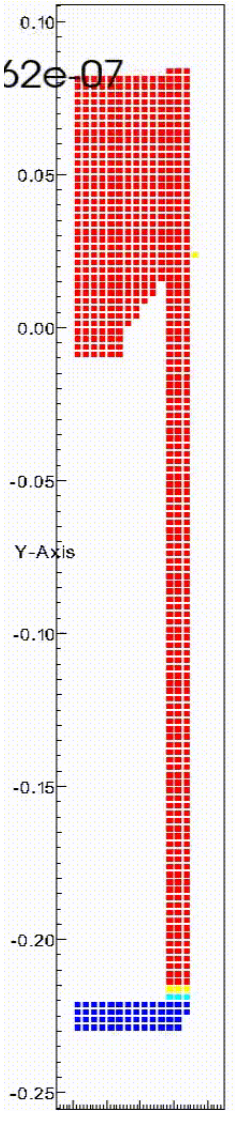
Fall cone test

Quickness test

Granular Material Point Method







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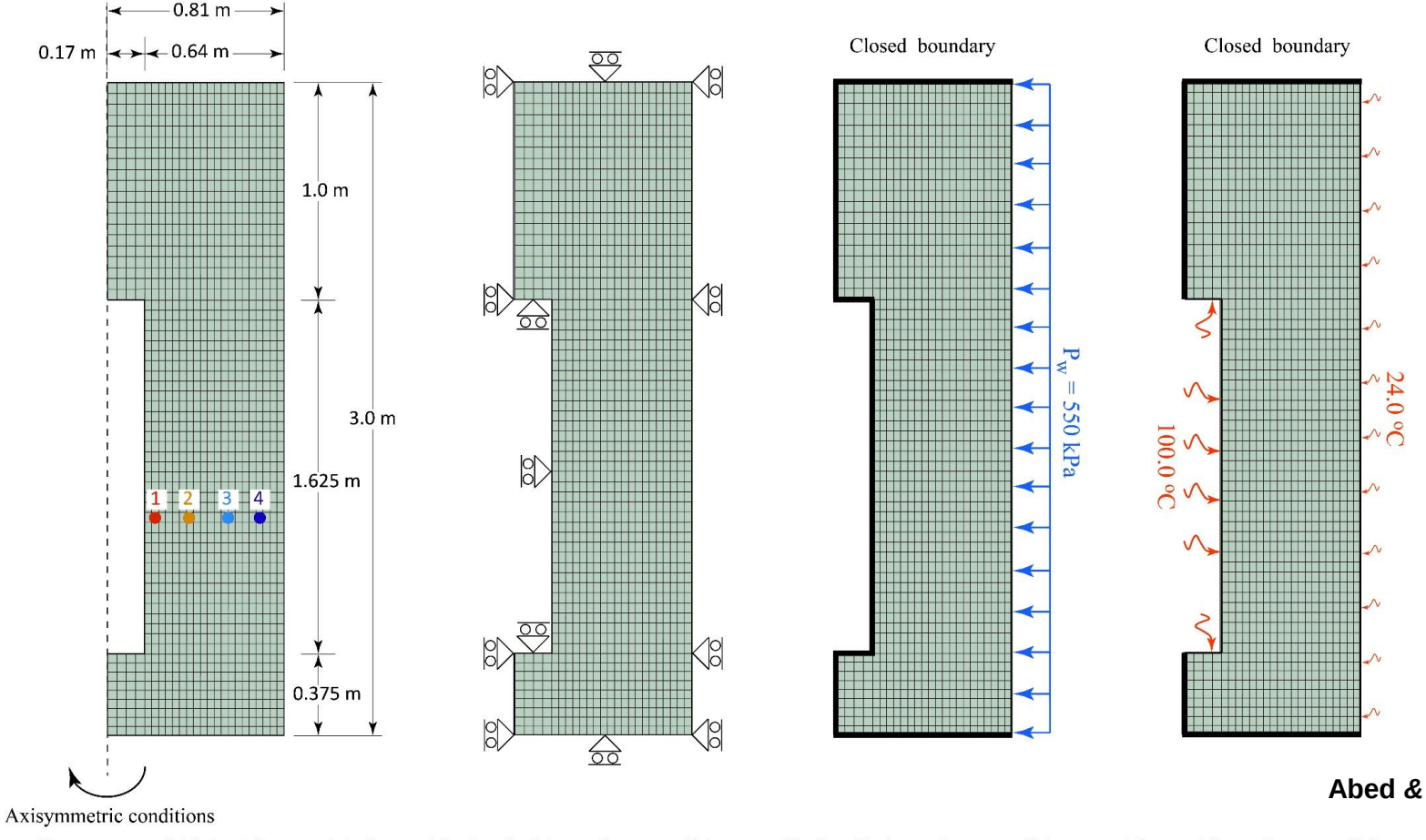
FE simulations: CIEMAT Mock-Up test

Example: Simulation of CIEMAT Mock-Up test for 2500 days (Martin et al. 2006)
The hydro-thermal coupling is based on the theory proposed by Philip & De Vries (1957).



Geometry and Finite Element Mesh | Mechanical boundary conditions | Hydraulic boundary conditions | Thermal boundary conditions

Abed & Sołowski (2017)

FE simulations: CIEMAT Mock-Up test

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Example: Simulation of CIEMAT Mock-Up test for 2500 days (Martin et al. 2006)
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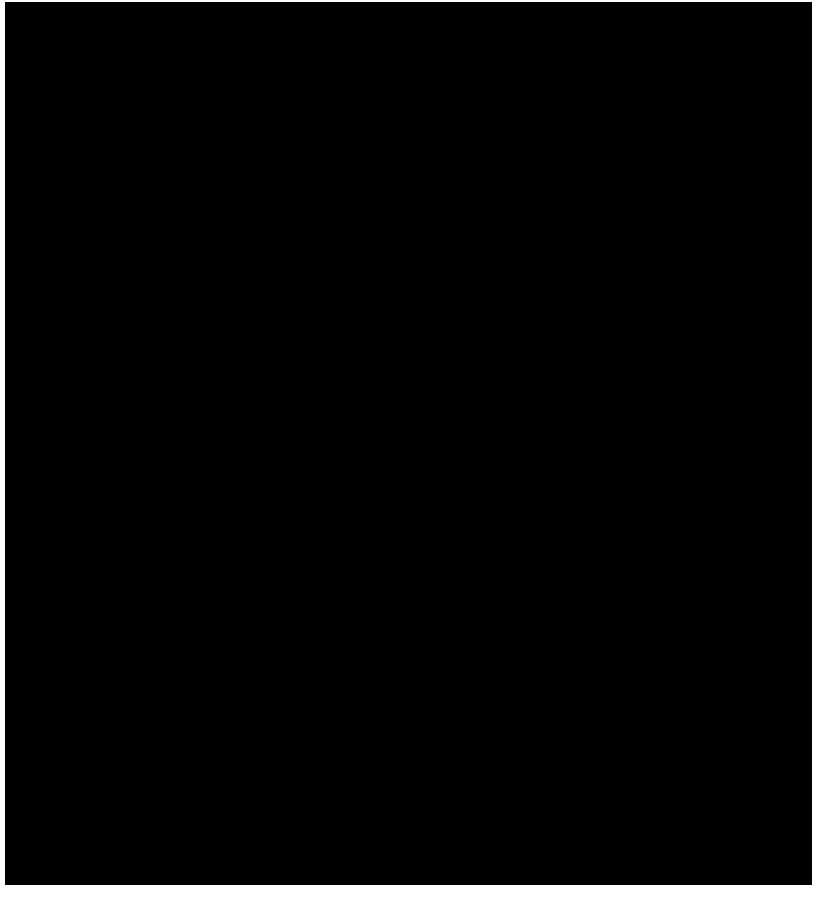

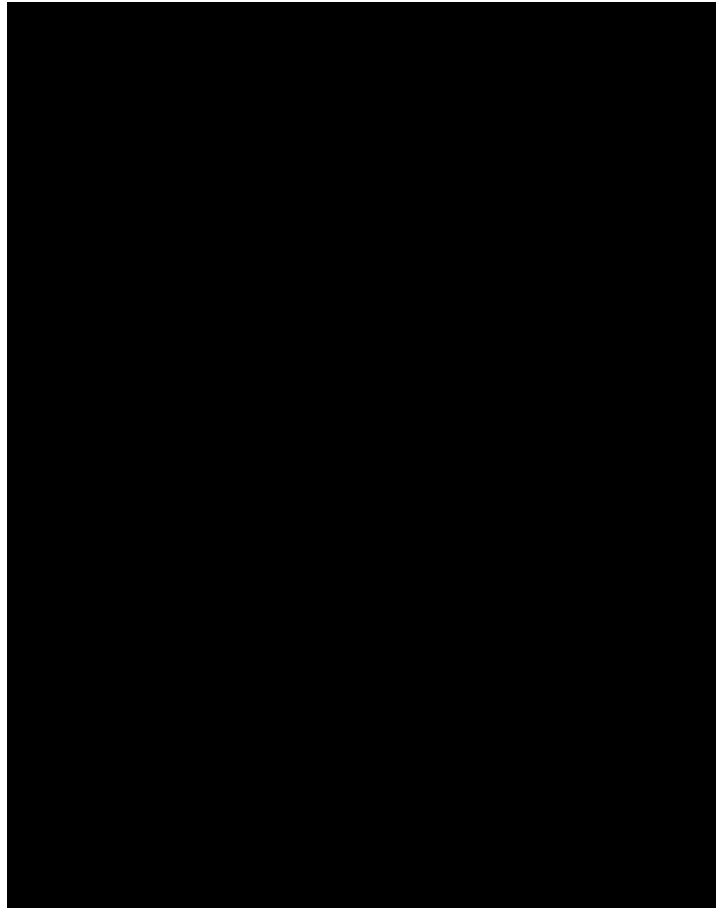

Abed & Sołowski (2017)

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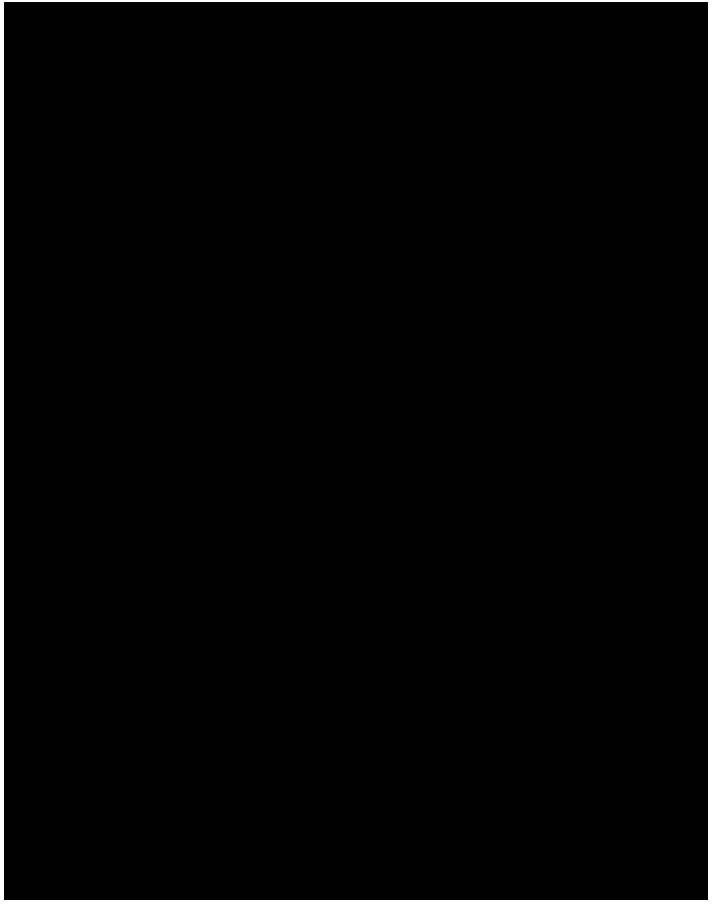

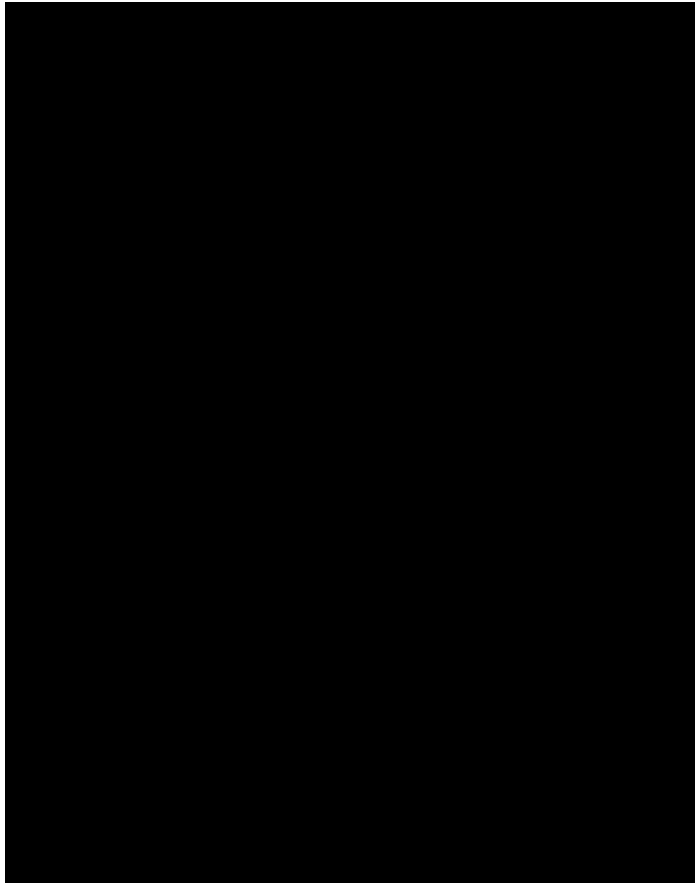

Abed & Sołowski (2017)

Associate Professor

Material Point Method research:

- Academy Project, dynamic soil exchange, CompactIt project
- Business Finland grant, vibrations due to dynamic soil exchange, DeMiCo project

Bentonite research: gas transport through bentonite, EU EURAD, Gas subproject

Offshore clay investigation: Geomeasure project with GTK

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Associate Professor

Bentonite research: gas transport through bentonite, EU EURAD, Gas subproject

- Hydrogen generated due to anaerobic corrosion of metal

$$Fe_{(s)} + 2\,H_2O \rightarrow Fe(OH)_2 + H_{2(g)}$$

- Gas pressure build up and migration
- THM(C) coupling and equations as in Abed et al. work.

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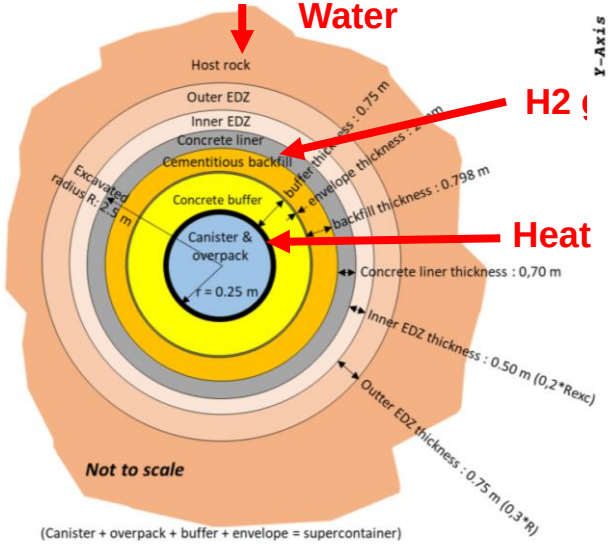
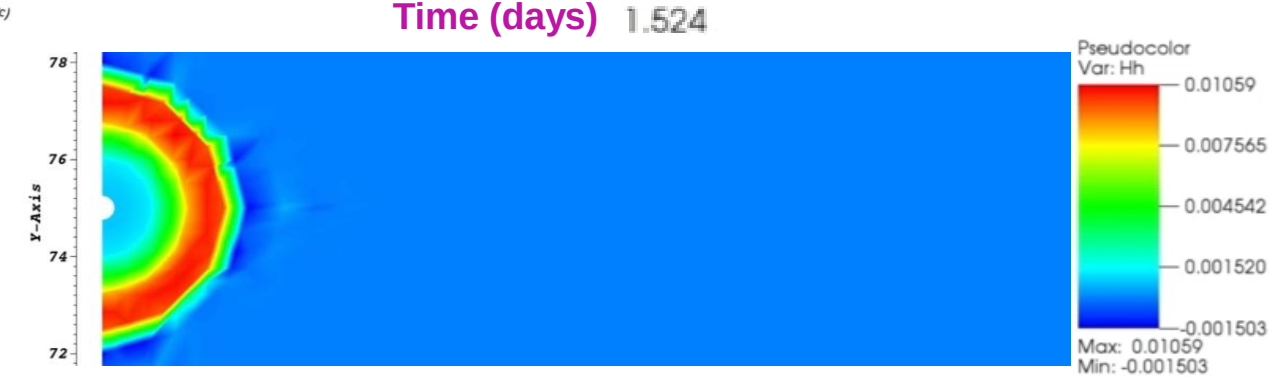
Application example: H2 gas is a potential threat to nuclear waste barrier



Temperature variation around the nuclear waste canister

Temp. (Degrees)



Hydrogen production at concrete steel liner

Hydrogen (m)

Abhishek Gupta

Gupta, A., Abed, A. A., & Solowski, W. T. (2023). Identification of key thermal couplings affecting the bentonite behaviour in a deep geological nuclear waste repository. Engineering Geology, 324, Artikkeli 107251. https://doi.org/10.1016/j.enggeo.2023.107251

Gupta, A., Abed, A., & Sołowski, W. T. (2023). Implementation and validation of pressure-dependent gas permeability model for bentonite in FEM code Thebes. E3S Web of Conferences, 382, Artikkeli 02005. https://doi.org/10.1051/e3sconf/202338202005

2 more journal papers are coming, one in review, one in writing.

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Chenjie Ruan

Chenjie Ruan
(doctoral student)
Funding: Dean’s scholarship

Continuation of the research:

- adapting Thebes code for modelling soil freezing and thawing, as well are frost heave
- new theory ☺

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Compact It

Duration: 2022 – 2026

Academy project, total budget 766,5 k€

Grant holder: Wojciech Sołowski

Methods: Granular Material Point Method simulations of low / zero emissions ground improvement methods

Aim: New desing guidelines, optimisation of tools for ground improvement

Academic partners: University of Utah, Chalmers University, Silesian University of Technology

Industrial partners: Menard, Elu Konsult, Ramboll Finland, AFRY, Väylävirasto

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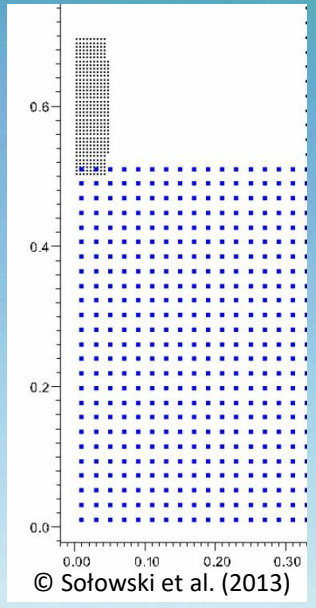
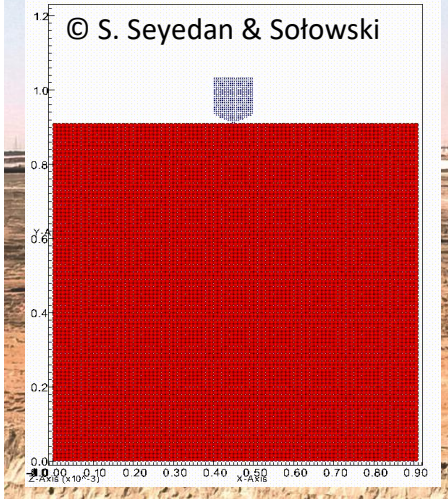


© Sołowski et al. (2013)

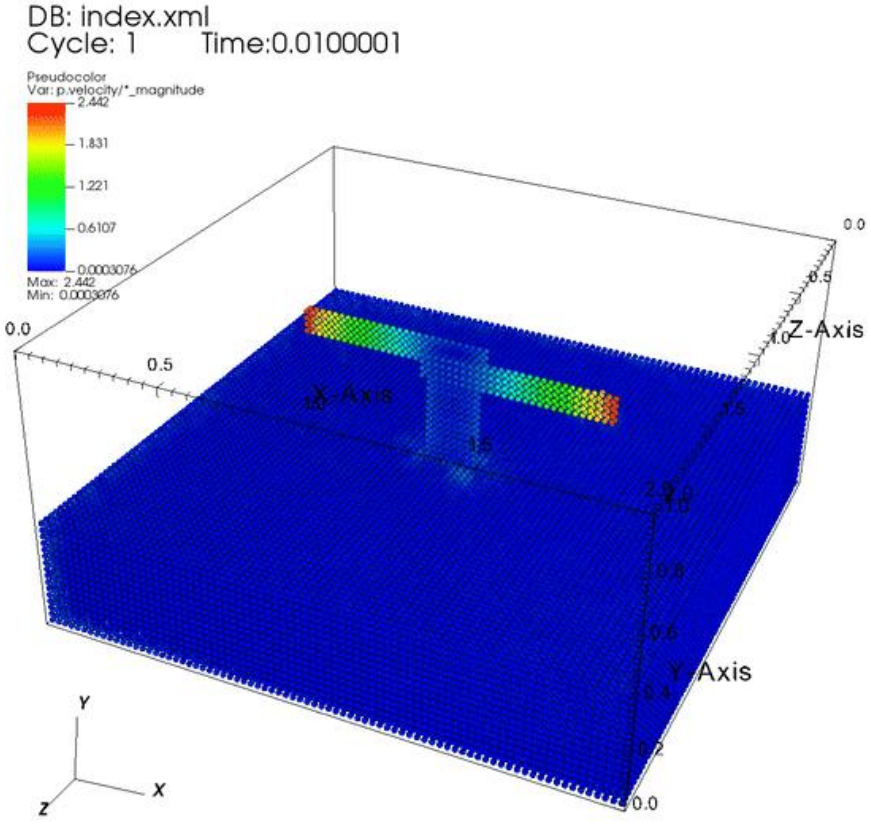


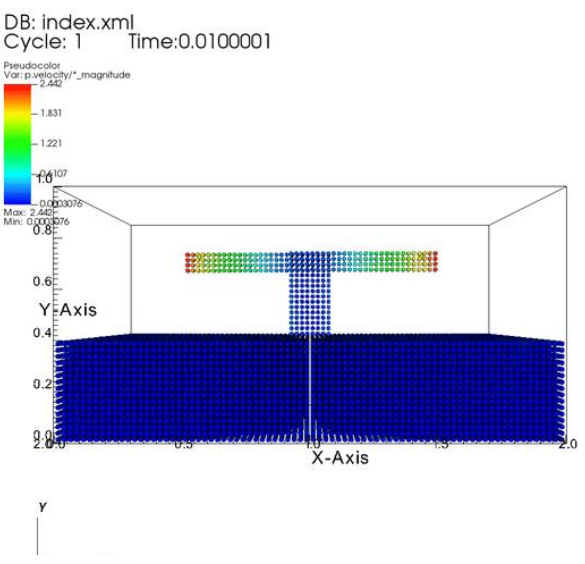
© Menard

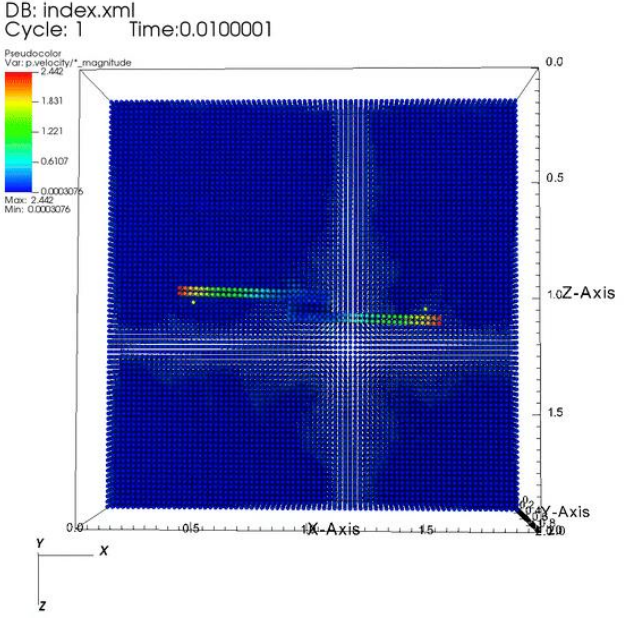
Deep mixing method: MA Ying, doctoral student

Simulation result:

Soil depth **0.4m**







DeMiCo

Work Package 2
Dynamic Replacement

Wojciech Sołowski

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Geomeasure

Wojciech Sołowski & Joonas Virtasalo

- Survey Finnish coastal areas
  - Remote sensing
  - Free-fall marine cone penetrometer tests
  - Core samples
- Laboratory testing of the core samples
  - Mechanical properties
  - Behaviour under cyclic loading
- Numerical replication of the free-fall penetrometer tests, new correlations between the tests and sample properties
- Methods for wind turbines foundations

More: solowski.info/geomeasure

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Geomeasure

Wojciech Sołowski & Joonas Virtasalo

Applications:

- Reliable surveying of seabed and accurate assessment of the seabed properties
- Simulation of interaction of structures and seabed
  - wind turbines foundations
  - seabed cables
  - underwater pipelines
  - risk of underwater landslides

More: solowski.info/geomeasure

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Geomeasure

Wojciech Sołowski & Joonas Virtasalo

Dr Saeideh Mohammadi

- Laboratory testing of soils
- Classification tests
- Triaxial tests
- Cyclic triaxial tests
- Simple shear tests
- Cyclic simple shear tests
- Cyclic testing model development
- Frost testing (next project?)

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Geomeasure

Wojciech Sołowski & Joonas Virtasalo

Dr Debasis Mohapatra

- Material Point Method simulation
- Photogrammetry analysis of experiments
- Small scale fall cone test
- Simulation of free fall penetrometer tests

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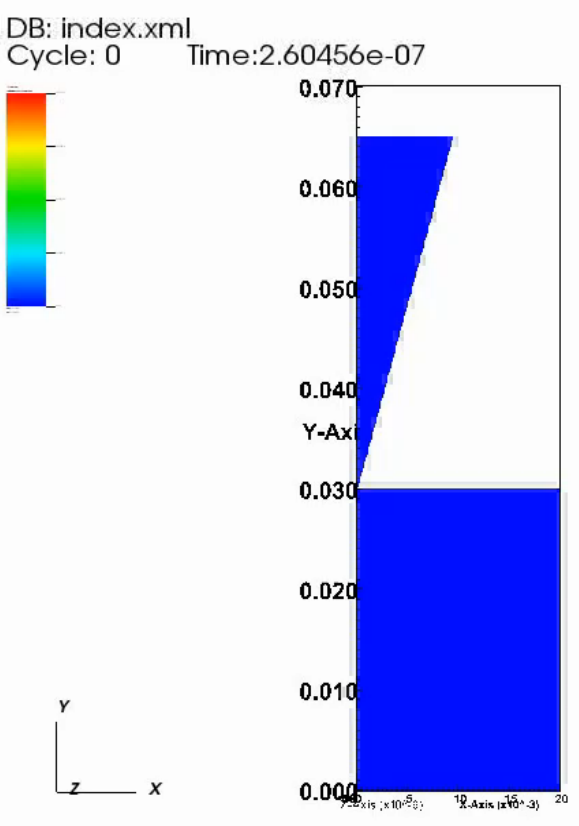
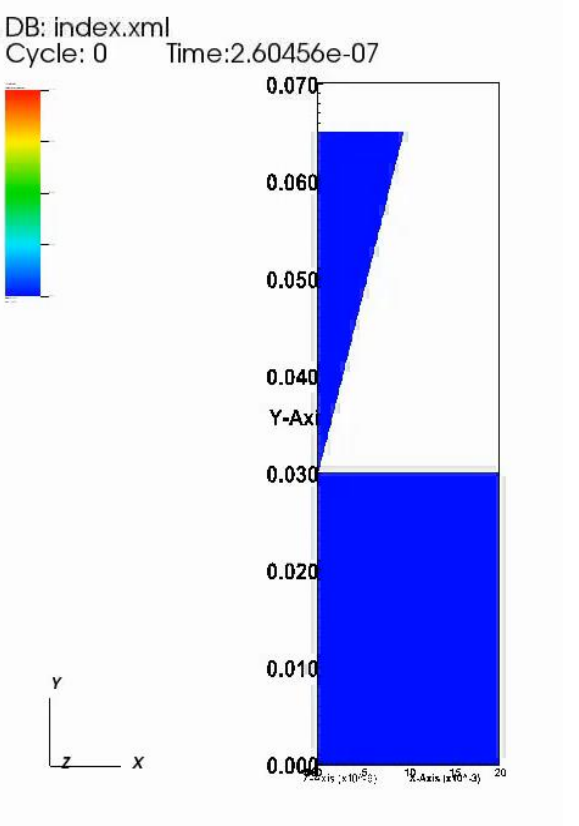
Fall cone test simulation using MPM

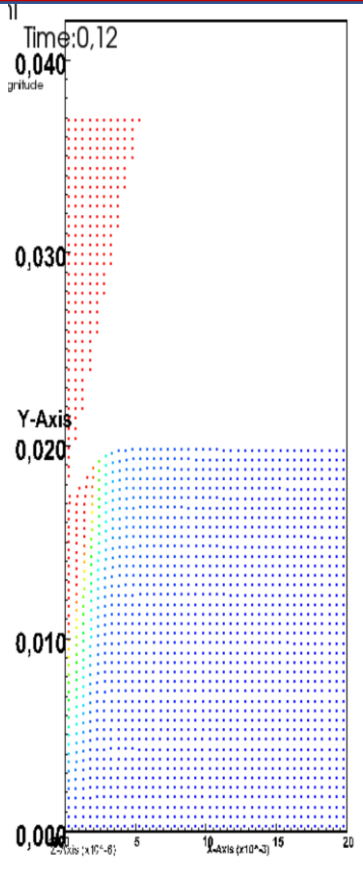
Displacement



Velocity

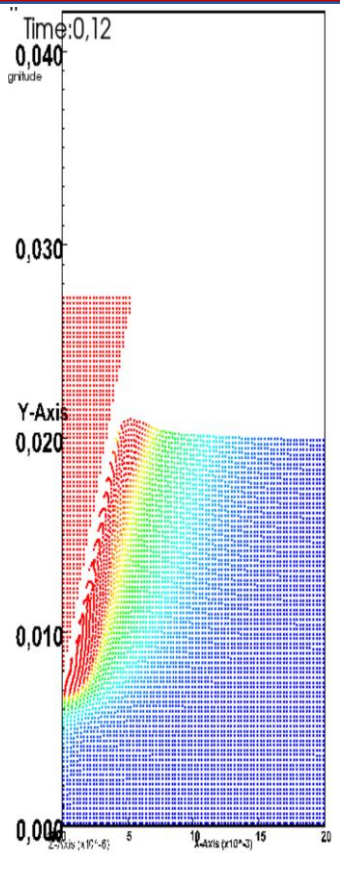


Effect of mesh density



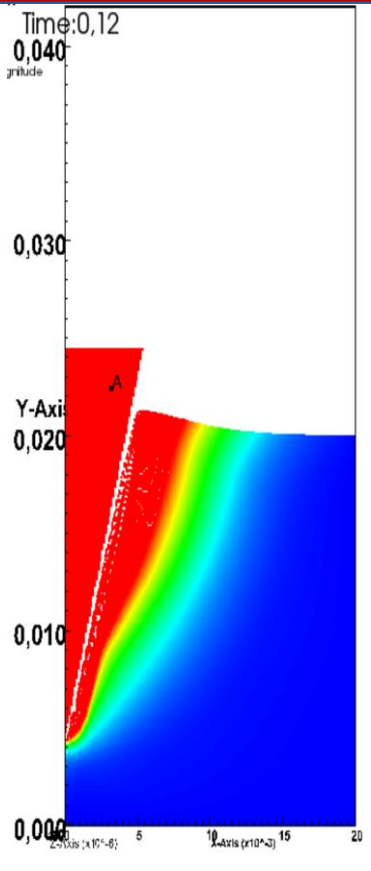
Mesh 1mm×1 mm

$d_p = 3.1\text{mm}$



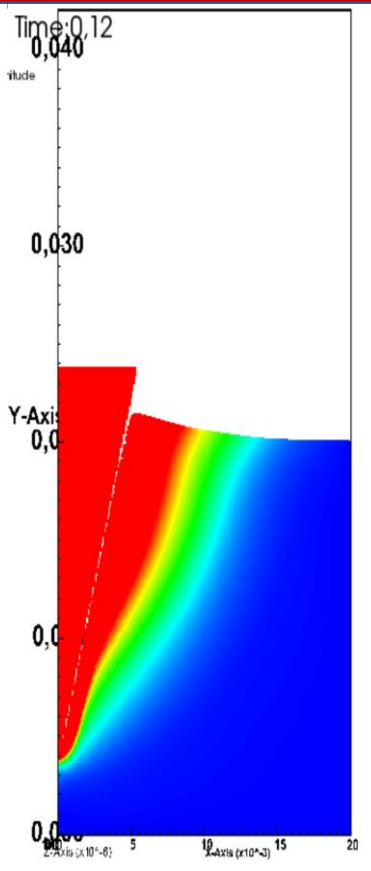
Mesh 0.5mm×0.5 mm

$d_p = 12.94\text{mm}$



Mesh 0.25mm×0.25 mm

$d_p = 15.7\text{mm}$



Mesh 0.15mm×0.15 mm

$d_p = 16.3\text{mm}$

Other research

- **Research for Väylävirasto**
  - Vibrations caused by trains
  - Frost heave susceptibility
  - Other research?
- **Numerical modelling, 2D, 3D, comparisons**
- **Model parametrization and use**
- **New constitutive models for soils**
- **Undrained shear strength, critical state**
- **Statistical interpretation of laboratory data**
- **Ideas, patents and cooperation with industry**

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Geotechnical Engineering Courses

Tough but doable schedule – first year

1. autumn I	II	1. spring III	IV	V
GEO-E1020 Geotechnics	GEO-E1030 Structural Design of Roads	GEO-E1040 Rock Excavation	GEO-E1010 Engineering Geology	GEO-E2020 Numerical Methods in Geotechnics
CIV-E1030 Fundamentals of Structural Design	GEO-E2080 Foundation Engineering and Ground Improvement	GEO-E3040 Geometric Design of Roads	GEO-E2010 Advanced Soil Mechanics	GEO-E2040 Rock Construction
	CIV-E1060 - Engineering Computations and Simulations	MS-E1653: Finite Element Method D	MS-E1653: Finite Element Method D	
	CIV-E1020 - Mechanics of Beam and Frame Structures	CIV-E4040 Reinforced Concrete Structures (CIV)	GEO-E2050 Bituminous Materials and Mixtures (Even years, next time 2024)	
			GEO-E3030 Road Maintenance and Rehabilitation (Odd years, next time 2025)	
Colors:				
Common studies (Compulsory)	**Advanced studies (Select at least 40 credits, 8 courses)**	**Elective Studies**		

Total: 75 credits, 5 credit CIV concrete

2nd year

2. autumn I	II	2. spring III	IV	V
GEO-E2030 Rock Mechanics	Master's Thesis 30 op			
Prestressed and Precast Concrete Structures D			GEO-E2050 Bituminous Materials and Mixtures (Even years, next time	
			GEO-E3030 Road Maintenance and Rehabilitation (Odd years, next time 2025)	

Total: 45 credits, 5 credit CIV concrete

Such a curriculum gives the most comprehensive education we can provide. If I calculated correctly, the curriculum will give you option to get highest FISE qualification in design of geotechnical structures (45 credits of Geotech + 15 Stuctural CIV) and infrastructure (10 credits of road design covered) , plus it has 10 credits in concrete allowing for some FISE qualification in rock mechanics (the level depends on interpretation).

Tough but doable schedule – first year

1. autumn I	II	1. spring III	IV	V
GEO-E1020 Geotechnics	GEO-E1030 Structural Design of Roads	GEO-E1040 Rock Excavation	GEO-E1010 Engineering Geology	GEO-E2020 Numerical Methods in Geotechnics
CIV-E1030 Fundamentals of Structural Design	GEO-E2080 Foundation Engineering and Ground Improvement	GEO-E3040 Geometric Design of Roads	GEO-E2010 Advanced Soil Mechanics	GEO-E2040 Rock Construction
	CIV-E1060 - Engineering Computations and Simulations	MS-E1653: Finite Element Method D	MS-E1653: Finite Element Method D	
	CIV-E1020 - Mechanics of Beam and Frame Structures	CIV-E4040 Reinforced Concrete Structures (CIV)	GEO-E2050 Bituminous Materials and Mixtures (Even years, next time 2024)	
			GEO-E3030 Road Maintenance and Rehabilitation (Odd years, next time 2025)	
Colors:				
Common studies (Compulsory)	**Advanced studies (Select at least 40 credits, 8 courses)**	**Elective Studies**		

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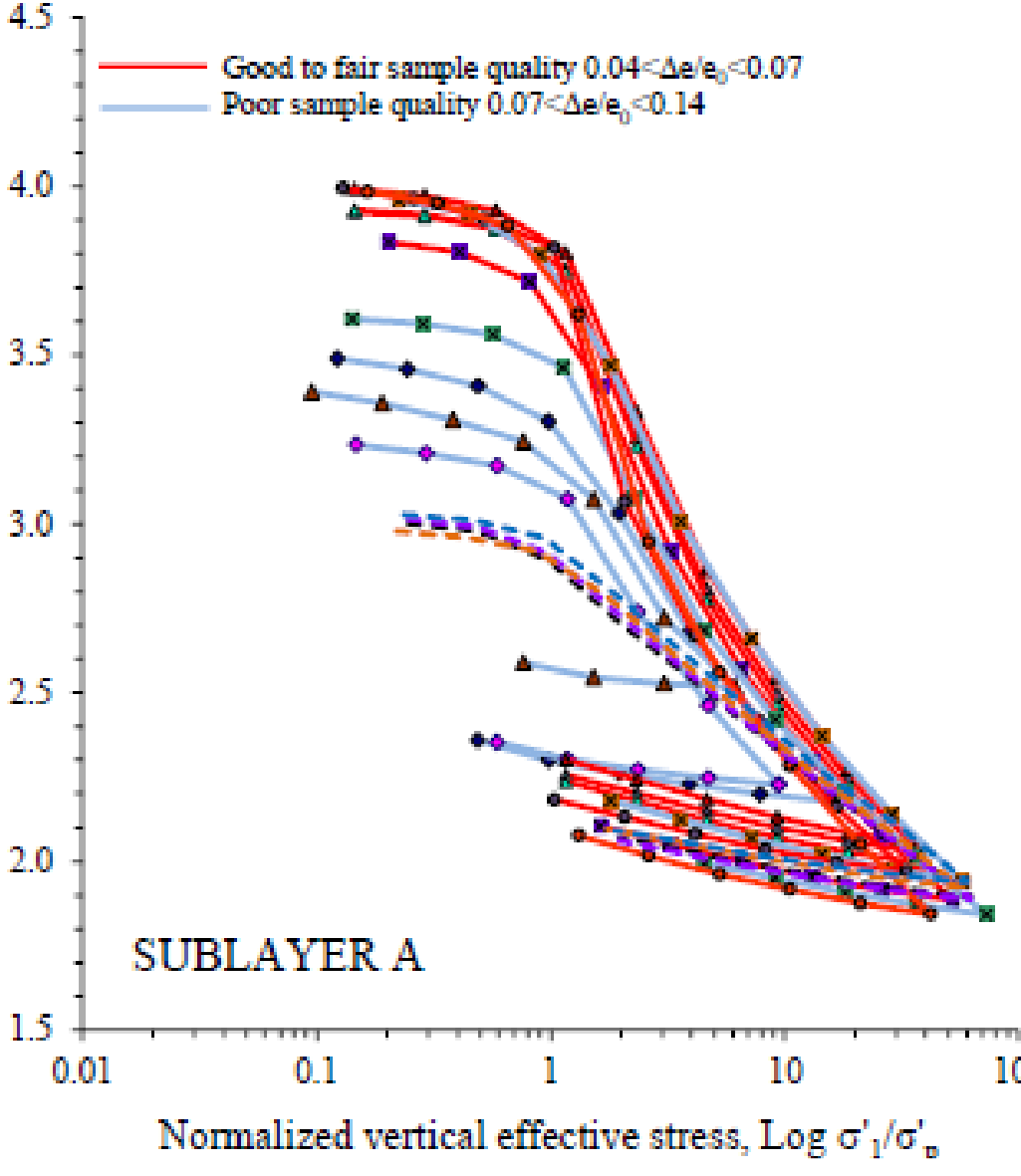
Total: 75 credits, 5 credit CIV concrete

GEO-E2010 Advanced Soil Mechanics

- Real soil behaviour
- Soil structure and microstructure
- Soil testing
- Constitutive models for soil
- Parameters estimation
- Critical State Soil Mechanics
- Water flow in soil



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GEO-E2010 Advanced Soil Mechanics

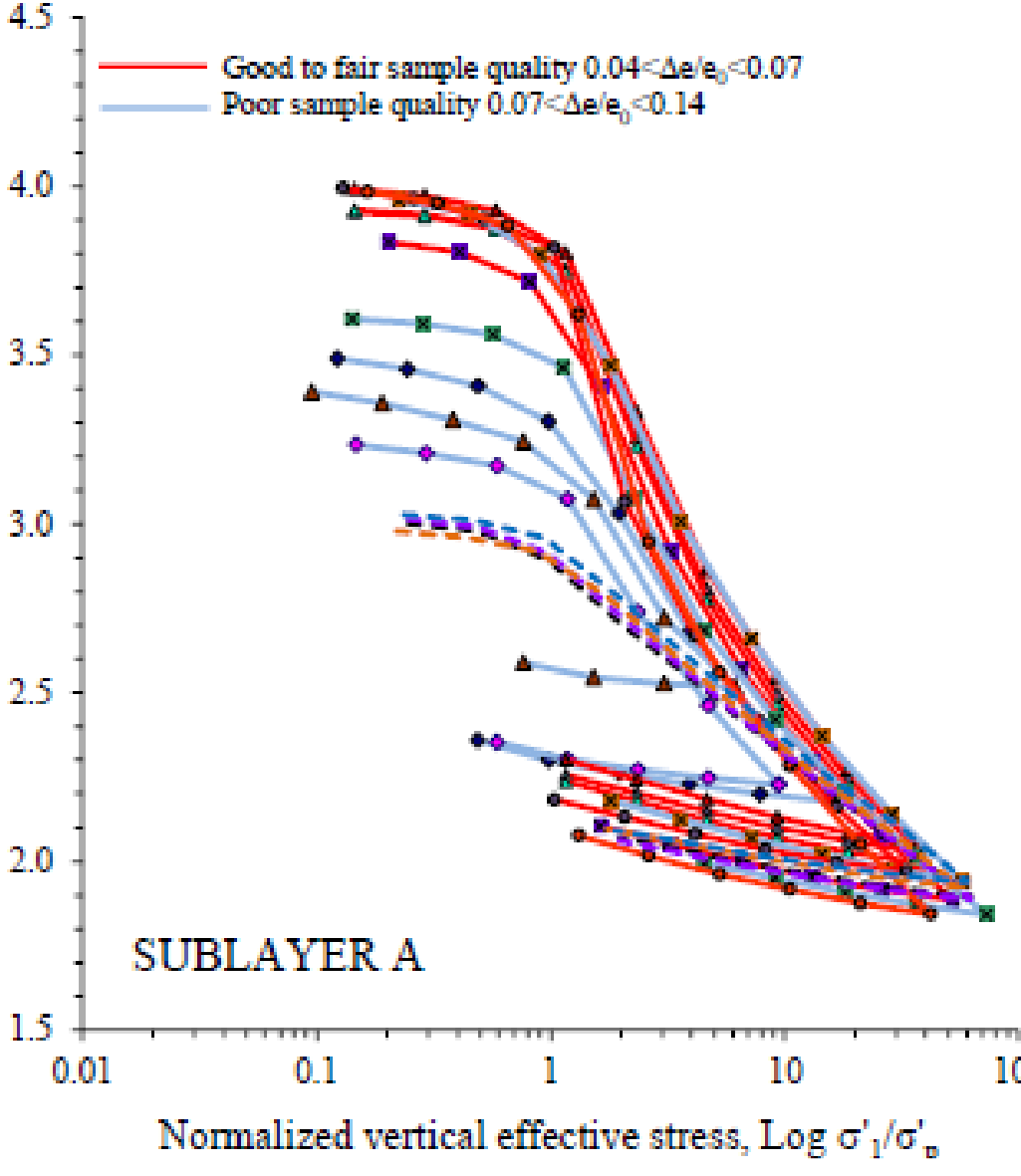
Obligatory prerequisites:

GEO-E1020 Geotechnics

GEO-E1080 Foundation Engineering and Ground Improvement

Suggested pre-requisites:

CIV-E1060 Engineering Computations and Simulations



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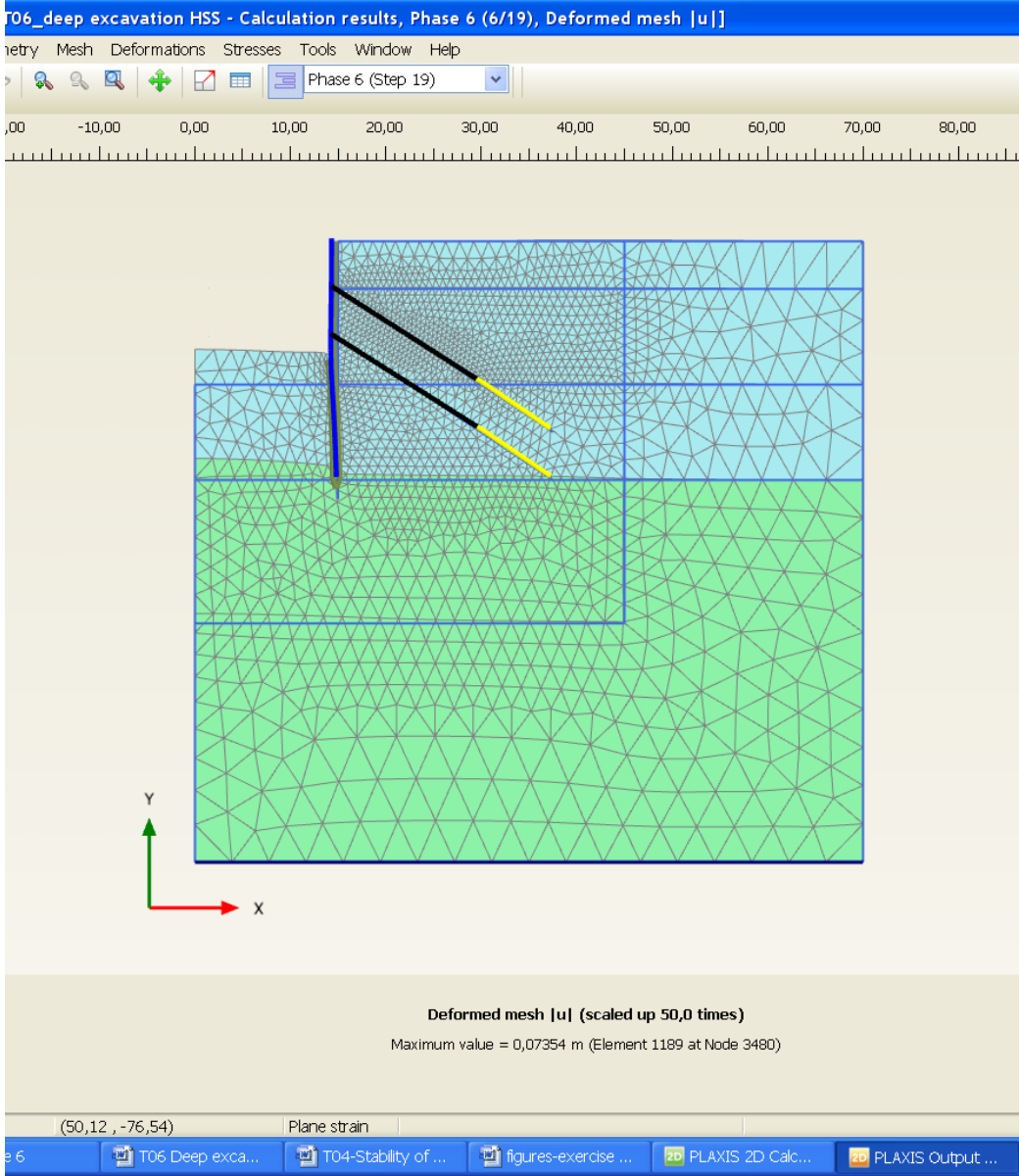
GEO-E2020 Numerical Methods in Geotechnics

- Finite Element method in geotechnics and geoengineering
- Plaxis 2D software
- Advanced soil models
- Advanced soil analysis



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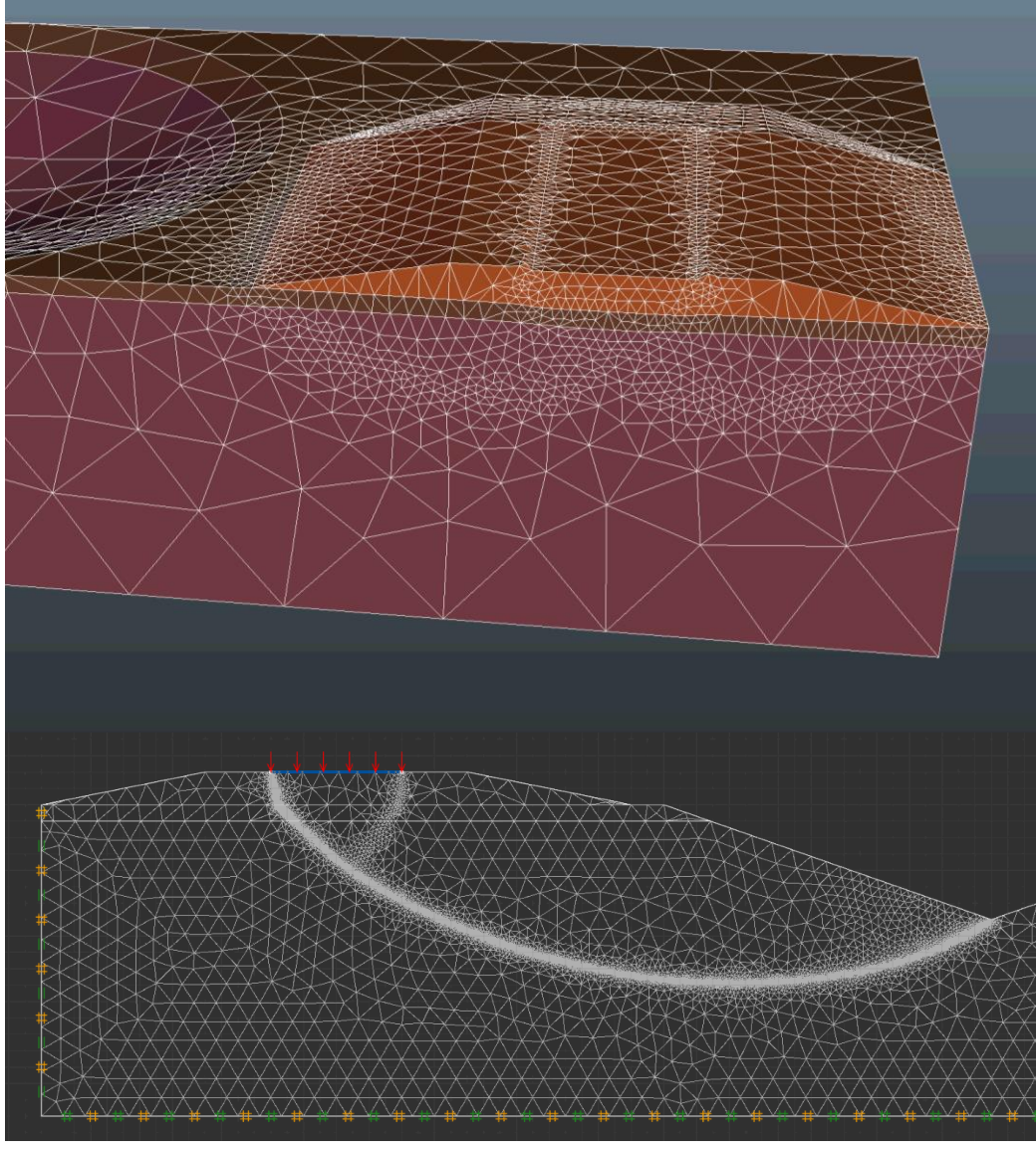
GEO-E2020 Numerical Methods in Geotechnics

- Possible to get up to 5 extra credits **5cr → 10 cr**
- There will be a number of options prepared, maybe including:
- Case studies
- Observational method example
- 3D calculations
- (case studies with external supervisor)



GEO-E2020 Numerical Methods in Geotechnics

Obligatory prerequisites:

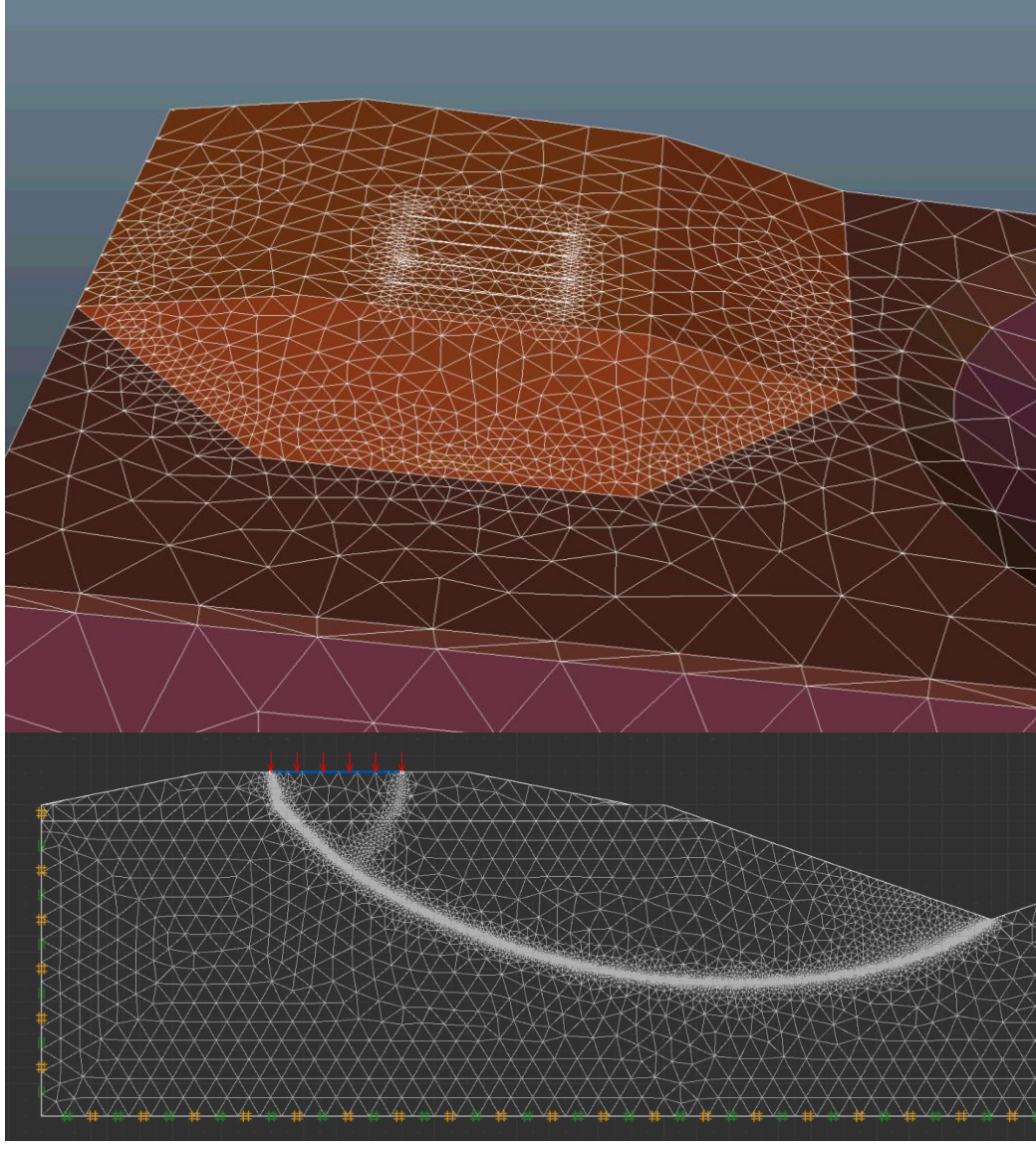
GEO-E2010 Advanced Soil Mechanics

Suggested pre-requisites:

CIV-E1060 Engineering Computations and Simulations

A Finite Element Method course, MS-E1653 or CIV-E4010 or…

Many others may be useful!



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Thank you