CIVIL-423

# Computational geomechanics

Lecampion Brice

| Cursus | Sem. | Type |
|---|---|---|
| Civil Engineering | MA1, MA3 | Opt. |
| Mechanics | | Opt. |

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| Language of teaching | English |
| Credits | 5 |
| Session | Winter |
| Semester | Fall |
| Exam | During the semester |
| Workload | 150h |
| Weeks | 14 |
| **Hours** | **5 weekly** |
| Lecture | 2 weekly |
| Exercises | 3 weekly |
| **Number of positions** | |

## Summary

The goal of this course is to introduce the student to modern numerical methods for the solution of coupled & non-linear problems arising in geo-mechanics / geotechnical engineering.

## Content

Fluid infiltrated porous media are ubiquitous all around us: concrete, soils, rocks but also wood, bones etc. Numerous engineering applications in civil, environmental, material sciences and bioengineering require the quantitative modeling of the combined mechanical deformation and fluid flow of porous geo-material.
The goal of this course is to introduce the student to modern numerical methods for the solution of coupled & non-linear problems arising in geo-mechanics / geotechnical engineering.
The course focuses on quasi-static deformation of fluid-infiltrated porous media, elastic and inelastic behavior under small-strain assumption, and the associated numerical algorithms.
The course is divided in 2 modules. The first module focuses on groundwater flow & linear poro-elasticity. During that part, the students will use a Matlab library (we are in the process of switching to Python) of finite element routines to script the numerical solution of such type of initial boundary value problems. Both verification tests examples as well as practical industry inspired problems (fluid storage at depth, flow around tunnels, earth dams, aquifer discharge, consolidation problems etc.) will be investigated.
The second module focuses on the numerical solution of non-linear problems, more specifically in relation to irreversible plastic geo-material behavior as well as the non-linear behavior of interfaces (e.g. fractures, joints). The coupling with structural elements & reinforcements (anchors etc.) will also be covered. The theory behind different type of numerical algorithms will be studied during the lectures. Illustrative engineering examples (dams, excavations, retaining walls, waste storage, tunnels etc.) will be investigated using commercial solvers (e.g. Optum G2). Here again the importance of code verification and sound analysis of numerical results will be emphasized.

## Keywords

numerical modeling, geomechanics, soil and rock mechanics

## Learning Prerequisites

### Required courses

- Continuum mechanics (e.g. CIVIL-225)
- Finite Elements (e.g. CIVIL-321)
- Numerical analysis (e.g. MATH-251a)

### Recommended courses

- Geo-mechanics (CIVIL-402)
- Soil mechanics & Groundwater seepage (CIVIL-203)
- Rock mechanics ( CIVIL-308)
- Geotechnical engineering ( CIVIL-306)

### Important concepts to start the course

- Kinematic description of a continuum
- mass, momentum & energy balance
- elastic and plastic behavior of materials
- variational principles
- linear algebra
- effective stress in porous material

## Learning Outcomes

By the end of the course, the student must be able to:

- Contextualise & create the necessary steps required to develop a numerical model of a geo-mechanical problem
- Assess / Evaluate the benefits of different numerical approaches for a given problem
- Choose the most adequate numerical techniques and solvers for a given geotechnical problem
- Interpret & judge the results of numerical solvers for the solution of poro-elastoplastic problems
- Develop numerical procedures for the solution of linear poroelastic problems
- Conduct numerical solutions for practical geotechnical problems

## Transversal skills

- Access and evaluate appropriate sources of information.
- Continue to work through difficulties or initial failure to find optimal solutions.
- Demonstrate the capacity for critical thinking
- Use both general and domain specific IT resources and tools
- Summarize an article or a technical report.

## Teaching methods

2 hours lectures - Reverse Teaching : Course notes for the week MUST be read prior to the class. Important points will then be re-emphasize during the class via a Quizz to kick off the discussions.
2 hours in computer room - focused on the numerical solution of a problem previously described during the lecture.

## Expected student activities

Student will be expected to be pro-active and read course material in advance. They will also need to finalize by themselves the numerical solution of the problems given every week.

## Assessment methods

*During the semester*
2 MCQ Tests (20% of the grade)
1 Homework (analysis of a particular problem, individual & different for each students ) (40% of the grade)
1 oral exam (40 % of the grade)

## Supervision

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| Office hours | No |
| Assistants | Yes |
| Forum | Yes |
| Others | Moodle etc. |

## Resources

### Bibliography

- Course notes & articles given during lectures
- Fundamentals of poroelasticity- Detournay & Cheng
- Plasticity & Geotechnics – Yu
- Any finite element textbook (Hughes, Zienkewitz etc.)

### Ressources en bibliothèque

- Fundamentals of poroelasticity- Detournay & Cheng
- Plasticity and Geotechnics â## Yu

### Moodle Link

- https://go.epfl.ch/CIVIL-423