Syllabus for ACE060 - Deep Foundations

7,5 Credits
Grading: TH – Five, Four, Three, Not passed
Education cycle: Second-cycle
Major Subject: Civil and Environmental Engineering
Department: 20 – ARCHITECTURE AND CIVIL ENGINEERING
Teaching language: English
The course is open for exchange students

Examiner
Jelke Dijkstra

Teachers
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Course specific prerequisites
Geotechnics (BOM355) or equivalent undergraduate basic soil mechanics course covering the following topics: effective stress, settlements, slope stability and earth pressure calculations.

Good basic knowledge of the subject of Applied Mechanics with applications within the area of deformations and strength of materials as well as evaluating stability of simple structures.

Aim
The aim of the course is equipping future Civil and Structural Engineers with up-to-date knowledge on techniques and methods of analyses needed for the geotechnical design of infrastructure and buildings. The focus is on construction in a densely populated urban environment, where the lack of space and environmental effects are a major concern. The techniques and methods are applied in practice as part of a design project that deals with the construction of an underground structure in an urban setting.

Learning outcomes (after completion of the course the student should be able to)

After completion of the course the following learning outcomes should be accomplished:

- Knowledge
    - Describe the principles, benefits and limitations of various foundation & retaining wall types and in-situ instrumentation and monitoring concepts.
- Comprehension
    - Distinguish the difference and select between undrained and drained analysis in the context of ultimate and serviceability limit state design
    - Appreciate the limitations of various analytical and numerical design methods for geotechnical structures.
    - To comprehend the role of the soil and the structure in the analyses of soil-structure interaction in context of retaining walls and foundations.
- Application
    - To calculate bearing capacity and settlements of shallow and deep foundations.
    - To calculate earth pressures (at rest, active, passive) for drained (long-term) and undrained (short-term) conditions.
    - To calculate stability of earth retaining structures.
- Analysis
    - To analyse stress paths in the soil adjacent to foundation elements.
    - To analyse the strength as a function of initial state and load path.
    - To predict stability and consolidation & creep settlements of foundations.
    - To analyse soil-structure interaction problems.
- Synthesis:
    - To integrate theoretical knowledge with engineering judgement to solve real-world problems, such as dimensioning of retaining walls and the response of shallow and deep foundations.
    - Comparison of predicted and expected soil response, e.g. comparing results of advanced numerical methods against monitoring data or hand calculations.

Organisation

As a Master's level course, the course relies on an active participation by the students. Lectures are supported by *tutorials* and *project work* (groups of max. 4 students) that integrates the various aspects of learning in a real geotechnical context.

The project work will contribute 100% of the final grade. **The assumption is that all group members get the same grade, however, please contact the examiner as early as possible in case this is perceived to be unfair.**

All documents related to the tutorials (exercises, worked solutions) and project work (document, groups, hand in) will be available in Canvas. Hand in of project work is on Canvas.

Refer to the separate document on the project requirements in Canvas.

Content

The course content in a nutshell (relevant topics for design project in bold)

- **Revisit basic concepts (mainly on lecture slides)**
- **Deep excavations (Swedish guidelines, Kempfert book & slides)**
- Shallow foundations (lecture slides)
- **Deep foundations (Fleming book & slides)**
- Ground improvement (lecture slides)
- Tunnelling in soft soils (lecture slides)
- Geotechnical monitoring (lecture slides)

Literature

Fleming, K. Weltman, A. Randolph, A. & Elson, A., (2008). *Piling Engineering, 3rd edition*, Taylor & Francis, ISBN 9780415266468, (e-book)
Kempfert, H-G. & Gebreselassie, (2006). *Excavations and foundations in soft soils*. Springer, (e-book)

Lecture slides and any additional material will be published on the course home page.

Complementary literature

ICE Manual of Geotechnical Engineering, Volume 2: Geotechnical design, construction and verification. ICE Publishing 2012. (e-book)
LimitStateGeo and Plaxis manuals

Examination

~~Written examination of 4 hours that contributes 60% to the final grade.~~
Due to COVID-19 remote teaching and examination the grade is totally dependent on the project work.

Detailed course content

- Introduction
    - Geotechnical design
    - Limit states
    - Observational Method
    - Principles of design and stress paths related to deep foundations and earth retaining walls
    - Earth pressures revisited- dependency of earth pressures on mobilised displacements
- Deep Excavations
    - Types of retaining walls (gravity, reinforced concrete, embedded walls), supports (props, anchors) and walling techniques (Berlin wall, sheet pile, contiguous and secant piles, diaphragm walls), including installation effects
    - Dewatering (wells & recharge wells)
    - Design of single and multi-propped embedded walls
    - Bottom heave and stability, methods for mitigating bottom heave (cross walls, deep mixing etc.)
    - Environmental impact
    - Construction sequence (top down, bottom up)
- Shallow foundations
    - Analytical methods
    - VHM design
- Deep Foundations
    - Pile types
    - Pile installation
    - Axially loaded piles (compression, tension)
    - Laterally loaded piles
    - Group effects
    - Cyclic and dynamic loads
    - Pile load tests (static, statnamic and dynamic)
- Tunneling in soft soils
    - Cut and cover
    - TBM
    - Settlement through
    - Compensation grouting
- Monitoring
    - Design concepts
    - Displacements (structure and soil)
    - (Excess) pore pressures in the soil
    - Measuring (contact) stress
    - Distributed sensing (strain and temperature)

Course schedule and detailed lecture topics – NOTE THAT courses/tutorials are now taught via chalmers.zoom.us links distributed via Canvas announcements

Datum	Time	L/E/T	Location	Who	Topic
Week 1					
Tue 24/3	13.15-15.00	Lec	SB-H7/zoom	JD	Introduction, geotech design
-”-	15.15-17.00	Lec	SB-H7/zoom	JD	Limit states, Observational method
Thu 26/3	13.15-15.00	Lec	SB-H7/zoom	JD	Earth pressures
-”-	15.15-17.00	Tut	SB-L400/SB-L408/zoom	JD/JI/HT	Earth pressures
Fri 27/3	13.15-15.00	Lec	SB-H7/zoom	JD	Stress paths and undrained strength
Week 2					
Tue 31/3	13.15-15.00	Lec	SB-H7/zoom	MaK	Design of retaining walls -part 1
-”-	15.15-17.00	Tut	SB-L400/SB-L408/zoom	MaK/JI	Ret. Struct, cantilever and single prop
Thu 2/4	13.15-15.00	Lec	SB-H7/zoom	MaK	Design of retaining walls -part 2
-”-	15.15-17.00	Tut	SB-L400/SB-L408/zoom	MaK/JI	Ret. Struct, cantilever and single prop
Fri 3/4	13.15-15.00	Lec	SB-H7/zoom	MaK	Design of retaining walls -part 3

Week 3					
Thu 16/4	13.15-15.00	Lec	SB-H7/zoom	JD	Dewatering + environmental impact **Introduction to design project**
	15.15-17.00	Tut	SB-L400/SB-L408/zoom	MaK/JI	Ret. Struct, multi-prop
Fri 17/4	13.15-15.00	Lec	SB-H6/zoom	JD	Shallow foundations
					Design project: form groups read project description and start implementing calculation framework for design of wall
Week 4					
Tue 21/4	13.15-15.00	Lec	SB-H7/zoom	JD	VHM design of shallow foundations
	15.15-17.00	Tut	SB-L300/SB-L308/zoom	JD/JI	Ret. Struct, multi-prop
Thu 23/4	13.15-15.00	Lec	SB-H7/zoom	JD	Deep foundations: pile types and installation
-"-	15.15-17.00	Tut	SB-D042/zoom	JD/MaK	Consultation design project
Fri 24/4	13.15-15.00	Lec	SB-H7/zoom	JD	ULS axially loaded piles
					Design project: geotechnical calculations for retaining wall
Week 5					
Tue 28/4	13.15-15.00	Lec	SB-H7/zoom	JD	SLS axially loaded piles
-"-	15.15-17.00	Tut	SB-L200/SB-L400/zoom	JD/JI/HT	ULS axially loaded piles
Week 6					

Tue 5/5	13.15-15.00	Lec	SB-H7/zoom	JD	Laterally loaded piles
	15.15-17.00	Tut	SB-L400/SB-L408/zoom	JD	SLS axially loaded piles
Thu 7/5	13.15-15.00	Lec	SB-H7/zoom	JD	Pile groups
-"-	15.15-17.00	Tut	SB-L400/SB-L408/zoom	JD/JI/HT	Laterally loaded piles
Fri 8/5	13.15-15.00	Lec	SB-H7/zoom	JD	Pile groups
					Design project: Piles, vertical equilibrium of final structure
Week 7					
Tue 11/5	13.15-15.00	Lec	SB-H7/zoom	JD/JI	Structural design of piles
-"-	15.15-17.00	Tut	SB-L400/SB-L408/zoom	JD/JI/HT	Pile groups
Thu 14/5	13.15-15.00	Lec	SB-H7/zoom	JD	Pile Load Tests
	15.15-17.00	Tut	SB-L400/SB-L408/zoom	JD/MaK	Consultation design project
Fri 15/5	13.15-15.00	Lec	SB-H7/zoom	MiK	Deep Mixing
					Design project: Piles, ULS design pile length & c-t-c
Week 8					
Tue 19/5	13.15-15.00	Lec	SB-H7/zoom	MiK	Deep mixing
-"-	15.15-17.00	Tut	SB-L400/SB-L408/zoom	MiK	Deep mixing
Week 9					
Tue 26/5	13.15-15.00	Lec	SB-H7/zoom		No lecture

-”-	15.15-17.00	Tut	SB-L400/SB-L408/zoom	JD/MaK	Consultation design project
Thu 28/5	13.15-15.00	Lec	SB-H7/zoom	JD	Monitoring/TBM
-”-	15.15-17.00	Tut	SB-L400/SB-L408/zoom	JD/MaK	Consultation design project
Fri 29/5	13.15-15.00	Lec	SB-H7/zoom	JD	Revision
Fri 29/5	18.00		Canvas		Hand in: Design project
					NO EXAM