The Hong Kong University of Science and Technology

UG Course Syllabus

CIVL 4750 Numerical Solutions to Geotechnical Problems

Fall 2023 [3–0–0:3]

INSTRUCTOR: Dr Jidong ZHAO Room 4606 (E-mail: jzhao@ust.hk)
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TIME AND VENUE: Friday 12:00 pm - 2:50pm Room 3207

COURSE OBJECTIVES & OUTCOMES

This course aims to provide students with necessary knowledge and numerical skills to solve practical geotechnical problems. Ample tutorial examples will be practiced offering students with hands-on experiences in using popular geotechnical software packages in practical design and analysis, in helping them to develop analytical skills and establish technical judgements and understanding on selection of model parameter, setup of models and verification of numerical solutions.

COURSE DESCRIPTION

The students will be taught to use knowledge of soil mechanics and geotechnical engineering and general-purpose computer software packages to solve practical geotechnical problems associated with seepage, slope stability, consolidation and piles. Commonly available computer programs based on the limit equilibrium method, finite difference method and finite element method will be the focus of the course.

PREREQUISITES

- MATH 230 (Introduction to Numerical Methods)
- CIVL 3730 (Fundamental of Geotechnics/Soil Mechanics)
- CIVL 3720 (Geotechnical Analysis and Design)

TENTATIVE COURSE SYLLABUS

1. Use of computers in geomechanics
- Using numerical methods and computers in geomechanics
- Analysis of a geotechnical / foundation engineering problem
- Analytical solutions to geotechnical problems
- Quick survey of numerical methods and programs
- Categorization of mathematical problems types
- Numerical errors

2. Introduction to the finite difference and finite element methods
- Strong formulation – Introduction to the finite difference (FD) method

- *Formulation of the problem*
- *Formulation of numerical solutions*
- *Solution procedures for an axially loaded 1D pile (by hand)*
- *Finite difference solution of Terzaghi's one-dimensional consolidation*

- Weak formulation – Introduction to the finite element method (FEM)
  - *Formulation of the problem*
  - *Finite element equations*
  - *Gaussian quadrature*
  - *Solution of the axially loaded pile problem*

3. Two-dimensional finite element method for seepage analysis

- Theory of volumetric water content and permeability functions
- 2D finite element formulations
- Use of Geo-Slope program SEEP/W
- ***Tutorials***: *Seepage analysis I (Steady-state analysis)*
  Seepage analysis II (Transient analysis-analysis of water infiltration)

4. Slope stability analysis

- Basic concepts
- Slope stability analysis methods
- USE of Slope/W
- Cooperation with finite element method
- ***Tutorials***: *Slope stability analysis using Slope/W (I)*
  Stability of a slope during rainfall infiltration (II)

5. Introduction to constitutive models of soils

- Basic principles
- Brief introduction to continuum mechanics
- Overview of constitutive models
- Introduction to elastic, perfectly plastic, and critical state models
- Determination of critical state soil parameters using laboratory tests
- Typical model parameters for soils and rocks

6. Two-dimensional finite element procedures for stress-strain analysis

- 2D finite element procedures and FE discretisation
- Mesh considerations
- Problems that can arise with elements
- Obtaining a convergent solution
- Applying initial and in-situ conditions
- Displacement boundary conditions
- Construction sequence
- Methods for undrained / drained / consolidation analyses
- ***Tutorials***: *Analysis of strip footing on sand using PLAXIS 2D*
  Analysis of excavation using a tie-back wall by PLAXIS 2D

7. Two-dimensional finite difference procedures and use of FLAC

- Background of FLAC
- General solution procedures
- Boundary and initial conditions
- Loading and sequential modelling
- Slope stability analysis–strength reduction technique

- ***Tutorials***: *Excavation analysis with FLAC2D*
  Slope stability analysis with FLAC2D

ASSESSMENTS

- Assignments (5, 50%)
- Group term Project (40%)
- Group project presentation (10%)

REFERENCES

- Zhao, J.D., 2021. CIVL 4750 Lecture Notes for *Numerical Solutions to Geotechnical Problems*, HKUST.
- GEO-SLOPE International Ltd. 2007. SEEP/W and SLOPE/W 2007 Manuals. www.geo-slope.com
- Itasca Consulting Group, Inc. 2000. FLAC Fast Lagrangian Analysis of Continua, V4.0, www.itascacg.com
- PLAXIS 2D/3D 2010 Manual. www.plaxis.nl