Addis Ababa University
Addis Ababa Institute of Technology
School of Civil and Environmental Engineering
Graduate Program in Geotechnical Engineering

Course Title: Finite Element Method Applications in Geotechnical Engineering
Course Code: CENG 6202
Credit Hours: 3
Program: Regular and Extension
Semester: II

Course Instructors:
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Pre-requisite:

Students must have the knowledge of the different soil constitutive models, knowledge of soil dynamics, good background of computer programing knowledge (FORTRAN/C++, Matlab/Mathematica)

Course Objectives:

- ✓ To provide the students with the concepts underlying within the different discretization methods.
- ✓ To provide students the concepts of formulation and solution strategy for the Finite Element Method.
- ✓ To teach students to gain the hands-on understanding of how FEMs work rather than black-box recipes.
- ✓ To introduce students with at least one of the state-of-the-art geotechnical engineering software.

Learning Outcomes of the Course Upon the successful completion of the course, students will gain the necessary knowledge that will help them:

- ✓ Define problem domain/boundary and discretize the domain for FE analysis.
- ✓ Define material constitutive model for the problem at hand for FE analysis.
- ✓ Formulate the equations of geotechnical engineering problem in the context of FEM.
- ✓ Solve the FE equations.
- ✓ Interpretation of results of the FEM analysis.

Course Outline

1. Mathematical Preliminaries and Tools
   - 1.1 Review of Matrix Algebra
   - 1.2 Solution Methods
   - 1.3 Introduction to MatLab/Mathematica

2. Finite Element Discretization and the Direct Stiffness
   - 2.1 General Overview
   - 2.1.1 Introduction to Computational Mechanics
   - 2.1.2 Discretization Methods
   - 2.1.3 Finite Element Method Variants
   - 2.1.4 What Does a Finite Element Look Like?
   - 2.1.5 The Finite Element Analysis Process
     - 2.1.5.1 The Physical FEM
     - 2.1.5.2 The Mathematical FEM
     - 2.1.5.3 Synergy of Physical and Mathematical FEM
   - 2.1.6 Interpretations of the FEM
     - 2.1.6.1 Physical Interpretations
     - 2.1.6.2 Mathematical Interpretations
   - 2.2 The Direct Stiffness Method
   - 2.2.1 Idealization
   - 2.2.2 Master Stiffness Equations
   - 2.2.3 The Direct stiffness Method Steps
   - 2.2.4 Discretization/Breakdown
   - 2.2.5 Assembly
   - 2.3 Finite Element Method Modeling
   - 2.3.1 Terminology
   - 2.3.2 Idealization
     - 2.3.2.1 Models
     - 2.3.2.2 Mathematical Models
     - 2.3.2.3 Implicit and Explicit Modeling
   - 2.3.3 Discretization
     - 2.3.3.1 Decisions
     - 2.3.3.2 Error Sources and Approximation
   - 2.3.4 The Finite Element Method
     - 2.3.4.1 Interpretation
     - 2.3.4.2 Element Attributes
   - 2.3.5 Classification of Mechanical Elements
     - 2.3.5.1 Primitive Structural Elements
     - 2.3.5.2 Continuum Elements
     - 2.3.5.3 Special Elements
   - 2.3.6 Assembly
   - 2.3.7 Boundary Conditions

3. Formulation of Finite Elements and Finite Element Modeling Tips

3.1 Variational Formulation of 1-D Bar Element/ Beam Element
3.2 2-D Finite Elements
3.2.1 Plane Stress Problems
3.2.2 Plane Strain Problems
3.3 3-D Finite Elements
3.4 The Isoparametric Element Representation
3.5 Finite Element Modeling Tips
3.5.1 Introduction
3.5.2 Meshing
3.5.3 Mesh refinement
3.5.4 Element aspect ratio
3.5.5 Physical interfaces
3.5.6 Shape selection/ preference
3.5.7 Loading
3.5.7.1 Principle of lumping
3.5.8 Initial and boundary conditions
3.5.9 Support conditions
3.5.10 Symmetry and anti-symmetry conditions

4. Computer Implementation of the Finite Element Method
4.1 Implementation of One-, Two-, and Three-Dimensional Finite Elements
4.1.1 Model Definition
4.1.2 Element Level Calculation
4.1.3 Assembling Process
4.1.4 Creating the FEM Equations
4.1.5 Solving the FEM Equations
4.1.6 Stress and Strain Recovery

5. Application of Finite Element Method in Geotechniques using FE based software
5.1 Deformation Analysis
5.2 Embankment/excavation construction
5.3 Excess pore-water pressures
5.4 Soil-structure interaction
5.5 Seepage analysis

6. Application of Finite Difference Method in Geotechniques using FD based software
6.1 Deformation Analysis
6.2 Embankment/excavation construction
6.3 Excess pore-water pressures
6.4 Soil-structure interaction
6.5 Seepage analysis

References:

i. Introduction to MatLab for Engineering students by David Houcque, Northwestern University, 2005.
ii. FEA in Geotechnical Engineering by David M. Potts and Lidija Zdravkovic, 1999.
iii. Finite Element Modeling for stress Analysis by Robert D. Cook, 1995.
iv. Finite Element Procedures by K. J. Bathe, Prentice Hall, 2014.
v. The Finite Element Method by O.C. Zienkiewicz (Vol. 1 & 2), 2000.

Methods of evaluation:

- Series of quizzes, projects/assignments (45%-65%)
- One final exam (25% – 50%)
- Class Activities (5%)
- Do not miss class lectures.

✓ Please note that you need to get a MatLab code installed into your laptop.