



National University of Engineering (UNI)

School of Civil Engineering
Syllabus 2026-II

1. COURSE

CE3G5. Finite Elements Applied to Geotechnical Engineering (Mandatory)

2. GENERAL INFORMATION

2.1 Course	: CE3G5. Finite Elements Applied to Geotechnical Engineering
2.2 Semester	: 9 th Semester.
2.3 Credits	: 4
2.4 Hours	: 4 HT;
2.5 Duration of the period	: 16 weeks
2.6 Type of course	: Mandatory
2.7 Learning modality	: Face to face
2.8 Prerequisites	: • CE2G2. Soil Mechanics II. (8th Sem) • CE2H1. Fluid Mechanics I. (7th Sem)

3. PROFESSORS

Meetings after coordination with the professor

4. INTRODUCTION TO THE COURSE

Finite Elements Applied to Geotechnical Engineering introduces the finite element method as a numerical tool for the analysis and design of geotechnical structures and problems that cannot be solved reliably with classical closed-form methods. Building on the shear-strength, consolidation, and design framework developed in Soil Mechanics II and the numerical modeling background introduced in Fluid Mechanics II, the course first develops the mathematical foundations of the finite element method (variational formulation, Galerkin approximation, finite element spaces, and error estimation) and then applies them to geotechnical-specific problems: boundary conditions, initial stress states, and staged-construction modeling; one-dimensional analysis of consolidation and pile-soil interaction; two-dimensional plane-strain analysis of excavations, embankments, and retaining structures; an introduction to dynamic numerical analysis of seismic geotechnical problems; and the constitutive soil models (Mohr-Coulomb, Cam-Clay, and Hardening Soil Model) that make nonlinear soil behavior tractable in finite element software. As part of the Geotechnical Engineering specialization track, the course prepares students to use modern numerical modeling tools in professional geotechnical design practice.

5. GOALS

- Derive and formulate the finite element method (weak formulation, Galerkin approximation, and error estimation) for boundary value problems.
- Establish appropriate boundary conditions, initial stress states, and staged-construction sequencing for geotechnical finite element models.
- Formulate one-dimensional finite element models for consolidation and pile-soil interaction problems.
- Develop two-dimensional plane-strain finite element models for excavation, embankment, and retaining-structure design problems.
- Analyze the dynamic response of geotechnical systems using numerical dynamic analysis.
- Select and apply constitutive soil models (Mohr-Coulomb, Cam-Clay, Hardening Soil Model) appropriate to nonlinear geotechnical finite element analysis.

6. COMPETENCES

ABET-1) An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics. (Usage)

ABET-6) An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions. (Usage)

ABET-2) An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors. (Usage)

7. TOPICS

Unit 1: Finite Element Method (6 hours)	
Competences Expected: ABET-1,ABET-6	
Topics	Learning Outcomes
- Weak (variational) formulation of boundary value problems and Sobolev spaces - Galerkin method: finite-dimensional approximation spaces and the stiffness matrix - Triangular and quadrilateral finite element spaces: Lagrange elements and conformity - A priori error estimates: Céa's lemma and interpolation error bounds - A posteriori error estimates and adaptive mesh refinement	- Derive the weak formulation of an elliptic BVP and show its equivalence to the strong form [Familiarity] - Assemble the global stiffness matrix and load vector for a linear finite element discretization [Usage] - Estimate the H^1 error of a finite element solution using Céa's lemma and interpolation theory [Assessment]
Readings : [Red19]	

Unit 2: Geotechnical Numerical Modeling and Applications (50 hours)	
Competences Expected: ABET-1,ABET-2,ABET-6	
Topics	Learning Outcomes
- Boundary conditions, initial stress state, and staged construction (excavation and fill sequencing) in geotechnical finite element models - Soil-structure interaction modeling: interface elements and contact behavior between soil and structural elements - One-dimensional numerical models for consolidation and axially loaded pile-soil interaction - Two-dimensional plane-strain numerical models for excavations, embankments, and retaining structures - Dynamic numerical analysis of seismic site response and soil-structure dynamic interaction - Constitutive soil models: Mohr-Coulomb, Cam-Clay, and Hardening Soil Model for nonlinear geotechnical analysis	- Explain the boundary conditions, initial stress state, and staged construction sequencing required for geotechnical finite element models [Familiarity] - Model soil-structure interaction using interface elements in a finite element mesh [Usage] - Formulate one-dimensional finite element models for consolidation and pile-soil interaction problems [Usage] - Develop two-dimensional plane-strain finite element models for excavation, embankment, and retaining-structure problems [Usage] - Analyze the dynamic response of geotechnical systems using numerical dynamic analysis [Assessment] - Select and apply appropriate constitutive soil models (Mohr-Coulomb, Cam-Clay, Hardening Soil Model) in nonlinear finite element analysis [Usage]
Readings : [PZ01], [ZTZ13], [Kra96]	

8. WORKPLAN

8.1 Methodology

Individual and team participation is encouraged to present their ideas, motivating them with additional points in the different stages of the course evaluation.

8.2 Theory Sessions

The theory sessions are held in master classes with activities including active learning and roleplay to allow students to internalize the concepts.

8.3 Practical Sessions

The practical sessions are held in class where a series of exercises and/or practical concepts are developed through problem solving, problem solving, specific exercises and/or in application contexts.

9. EVALUATION SYSTEM

***** EVALUATION MISSING *****

10. BASIC BIBLIOGRAPHY

- [Kra96] Steven L. Kramer. *Geotechnical Earthquake Engineering*. Prentice Hall, 1996.
- [PZ01] David M. Potts and Lidija Zdravković. *Finite Element Analysis in Geotechnical Engineering: Theory and Application*. Thomas Telford Publishing, 2001.
- [ZTZ13] O. C. Zienkiewicz, R. L. Taylor, and J. Z. Zhu. *The Finite Element Method: Its Basis and Fundamentals*. 7th. Butterworth-Heinemann, 2013.
- [Red19] J. N. Reddy. *An Introduction to the Finite Element Method*. 4th. McGraw-Hill, 2019.