IIT Mandi

Proposal for a New course (Revised)

Course Number: CE606

Course Name: Constitutive Modeling of Frictional Material

Credits: 3-0-0-3

Prerequisites: Geotechnical Engineering I (CE302) or Equivalent/ Mechanics of Solids (ME206) or Equivalent

Intended for: B.Tech. 4^{th} year/ M.S./ M.Tech./ Ph.D.

Distribution: Open Elective

Semester: Odd/Even

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1. Preamble:

Constitutive modeling of geomaterial plays a pivotal role in numerical analysis and design of complex geotechnical structures. The course aims to develop a basic understanding of various constitutive models pertinent to pressure-dependent/frictional materials, such as soils, rocks and concrete, with focus on their underlying assumptions and limitations. Further, it also involves hands on implementation of different constitutive models for geomaterials, which serves the main backbone of material response in any finite element computation of complex geotechnical structures. Starting with the basic concepts of continuum mechanics, the macroscopic response of geomaterials will be discussed in relation to the constitutive modeling. Different elastic and elasto-plastic modeling concepts will be explained along with due consideration to the model calibration and implementation procedure. The course will be concluded with discussions on advanced constitutive models which are relevant for mimicking material behavior under specific cases, for example, blasting, earthquake or unsaturated condition to name a few.

2. Course Modules with Quantitative Lecture Hours:

Module 1: Mathematical Background **(6 lecture hours)**

Overview and importance of constitutive modeling; Preliminaries on tensor; Stress, strain and invariants; Principal stress space: triaxial and octahedral plane; Stiffness tensor; Voigt notation.

Module 2: Constitutive Behavior of Geomaterials **(3 lecture hours)**

Different laboratory tests and various modeling aspects pertinent to the stress-strain behaviour of geomaterials subjected to shearing and volumetric compression, e.g., void ratio, pressure and stress path dependency, anisotropy and rate/time effects etc.

Module 3: Elasticity **(6 lecture hours)**

Linear, nonlinear and anisotropic elastic models; Calibration of model parameters.

Module 4: Plasticity **(7 lecture hours)**

Internal variable, yield criteria, flow rule, plastic potential, Drucker's stability postulate, convexity and normality rules, hardening/ softening, isotropic and kinematic hardening; Different failure criteria for yielding: Tresca, von Mises, Mohr-Coulomb, Drucker-Prager, Hoek and Brown etc.

Module 5: Critical State Models **(6 lecture hours)**

Critical state concept; Stress-dilatancy theory; Strain hardening and/or work hardening plasticity models for sand: formulation, calibration and implementation to simulate drained and undrained triaxial test.

Module 6: Cam-Clay Models **(10 lecture hours)**

Cam-Clay models: formulation and calibration; Implementation of Cam-Clay model to simulate single element tests: consolidation, drained and undrained triaxial test, Application of elasto-plastic models.

Module 7: Special topics **(4 lecture hours)**

Other advanced constitutive models for frictional materials (e.g., damage plasticity/ visco-plasticity/ unsaturated soil model/ disturbed state model etc.)

3. Text Book:

(i) David Muir Wood, Soil Behaviour and Critical State Soil Mechanics, Cambridge University Press, 1991.

(ii) Alexander Puzrin, Constitutive Modelling in Geomechanics, Springer, 2012.

4. References:

(i) David Muir Wood, Geotechnical Modelling, CRC Press Taylor and Francis Group, 2004.

(ii) W.F. Chen and E. Mizuno, Nonlinear analysis in soil mechanics: theory and implementation, Elsevier Science Ltd, 1990.

(iii) Hai-Sui Yu, Plasticity and Geotechnics, Springer, 2006.

(iv) W.F. Chen and G.Y. Baladi, Soil Plasticity: Theory and Implementation, Elsevier Science Ltd, 1985.

(v) C.S. Desai, Mechanics of Materials and Interfaces: The Disturbed State Concept, CRC Press Taylor and Francis Group, 2000.

(vi) N.S. Ottosen and M. Ristinmaa, The Mechanics of Constitutive Modeling, Elsevier Science, 2005.

(vii) J.C. Simo and T.J.R. Hughes, Computational Inelasticity, Springer, 2000.

(viii) E.A. de Souza Neto, D. Peric and D.R.J. Owen, Computational Methods for Plasticity: Theory and Applications, Wiley, 2008.

(ix) Allan F. Bower, Applied Mechanics of Solids, CRC Press Taylor and Francis Group, 2009.

5. Similarity Content Declaration with Existing Courses:

Sl. No.	Course Code	Similarity Content	Approximate % of Content
1	IC242	Tensor; Stress, strain and stiffness tensor; Invariants	<5%
2	ME206	Stress and strain definition; Theory of yielding	<3%
3	CE301	Concepts of stress and strain; Elastic constants and their relationships	<3%
4	CE302	Stress strain curve, Mohr-coulomb failure criteria, pore pressure, total and effective stress	<3%
5	ME607	Elastic deformation; The phenomenon of yield point and strain hardening.	<5%

6. Justification for new course proposal if cumulative similarity content is > 30%:
Not Applicable.

Approvals:

Other faculty interested in teaching this course:

Proposed by: Dr. Mousumi Mukherjee

School: School of Engineering (SE)

Signature:

Date:

Recommended / Not Recommended, with comments:

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Chairman, CPC

Date:

Approved / Not Approved

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Chairman, Senate

Date: