



Module Title	Constitutive Modelling of Geotechnical Materials
Credits	15
Co-Ordinator	Paul Shepley
Semester	Spring
Unit Description	<p>This module provides an overview of constitutive modelling in geotechnical engineering. Soils are complex particulate materials whose behaviour is highly non-linear and dependent on the stress state of the soil. As a result, simple calculations are insufficient to represent a soil's response to loading, and a more representative analysis (especially where accurate displacements need to be known) is required through developing a constitutive model. This module will discuss the features of constitutive models, compare them to real soil behaviour, and apply them to geotechnical structures, using a combination of case studies and applied examples.</p>
Unit Aims	<ol style="list-style-type: none">1. To describe and discuss constitutive modelling in comparison with other modelling techniques2. To discuss and critique different constitutive models in order to select the most appropriate model for a given problem3. To assess soil data and determine the required parameters for a reasonable constitutive model
Syllabus	<p>Introduction</p> <ol style="list-style-type: none">1. Define the difference between a numerical and constitutive model2. Frame reasoning of module through examples, such as the Nicoll Highway collapse3. Summary over basic soil mechanics; stress/strain relationships, Mohr's circles of stress, drained/undrained behaviour, plane strain/stress. <p>Introduction to constitutive models</p> <ol style="list-style-type: none">1. Purpose of constitutive modelling2. Philosophy of constitutive modelling - how many parameters are required, complexity vs. ease of use, "correctness" of output. <p>Simple constitutive models</p> <ol style="list-style-type: none">1. Mohr-Coulomb models2. Review s-t, p-q spaces3. Introduction to critical state framework (with examples) with effects of preconsolidation pressures and drained/undrained loading. <p>Modelling aspects</p> <ol style="list-style-type: none">1. Work done / energy balances2. Plasticity

3. Normality rules and yield surfaces
4. Compare models with observed soil behaviours - therefore the limits of modelling and how these can only represent certain behaviours

Extended constitutive models

1. Predominantly extensions to Cam Clay for strain hardening, and other phenomena.

Numerical implementation

1. Introduction to numerical methods: continuum FE/FD vs discontinuum DEM
2. Implementation of an example in OASYS

Learning Hours

Learning Hours of the Unit		
Activity	Remarks	Hours
Lectures	Lectures	18
Tutorials	Tutorial Classes	10
Seminars	Seminars	4
Independent Study (including Prep for Assessment)	Directed Reading and Directed Internet-based Research	20
Independent Study (including Prep for Assessment)	Private Study including Group Working	68
Coursework	Present key concepts, theory and analysis methods	30

Total Hours 150

Teaching Methods

The module will be delivered through a series of lectures, tutorials and seminars. An introductory handout will be disseminated before the start of the module to aid student preparation in basic soil mechanics that will be covered in the first week. Subsequent lectures will be given, followed by weekly tutorials to test students are following the course. Tutorial problem sheets will be used to structure the classes. These sessions will cover the more technical aspects of the course, in line with LO2-6. Case study examples will be frequently used to aid conceptualisation of the material, but reading - both directed and individual - will also be expected as students undertake individual study.

Seminars will be held to facilitate a wider class discussion over constitutive modelling. These will explore ideas from the lectures, tutorials and supplementary reading and develop a deeper understanding of the material. Students are expected to be involved in the discussions (LO1), whilst developing communication and critical thinking skills.

H&S / Risk
Management

Constitutive modelling is fraught with dangers if applied incorrectly, and can have potentially catastrophic effects (e.g. Nicoll Highway collapse). This course will give students an awareness of the fundamentals of constitutive modelling, such that they can allow for the inherent difficulties arising from using such models during engineering design. This ought to give students confidence in selecting and using the correct constitutive model to appropriately assess the stability of geotechnical structures.

Learning
Outcomes

1. Discuss constitutive modelling and compare with other geotechnical analysis methods
2. Summarise and compare the main features and uses of a constitutive model
3. Select and justify parameters to be used in a constitutive model
4. Construct appropriate yield surfaces
5. Implement constitutive modelling to assess the stability of a geotechnical structure
6. Evaluate a constitutive model and determine its relevance to a given geotechnical problem

Assessment
Methods

The module will be assessed through three key points. Additional formative assessment will arise from the tutorial worksheets which provide additional examples to the lecture material but carry no credit.

All assessment is aimed to gauge a student's knowledge over the concepts of constitutive modelling in geotechnics, rather than direct recall of specific models. A few models will be used during lectures to facilitate learning, but students should remember that there are a large number of models available that will not be taught during the course. Students are encouraged to read about additional models during their individual study periods.

Seminars will be used primarily to assess LO1 (but will also relate to LO2-3). Student participation will be expected, with opportunities for students to present and discuss their ideas with their peers. This is to encourage student participation in debates, their reading around the subject and broaden their wider knowledge.

A mini coursework project will assess student ability in the more technical aspects of constitutive modelling and their application to a problem (LO3 and LO5). This will be in the context of using constitutive modelling to assess the stability of a geotechnical structure.

A final exam will then be used to ensure students technical ability for identifying modelling parameters from soil data (LO3), ability to construct a yield surface (LO4), as well as capabilities to identify and select appropriate constitutive models for a given problem (LO6)

preliminary breakdown: 5+5% in 2 MOLE quizzes [70% minimum mark], 10% seminar, 25% coursework, 55% exam [2hr]

Assessment
Philosophy

The module assessment will focus on the fundamental concepts with regards to constitutive modelling in geotechnics. A small selection of models will be presented through the taught material, but students are welcome to include more models (where appropriate) during their assignments.

Feedback will be given wherever possible - notably through the seminars and weekly tutorials. These will allow students to attempt practice problems or discuss issues regarding constitutive modelling to ensure their thinking is correct.

Assessment will be given in four parts, through student input to seminars and intermediate MOLE quizzes, to the coursework and final exam. MOLE quizzes will be issued in week 1 and week 4 to ensure students are keeping up with the course material. The seminars and coursework will be assessed prior to the final examination, such that timely feedback is given in advance of the final examination.

Feedback on the module from students will be taken through an online questionnaire following the completion of lectures. Additional feedback will be requested throughout the module through an anonymous 'comments box' left at each tutorial for further feedback to be delivered to the module leader such that actions can be made accordingly. Any arising actions will be highlighted to students at the subsequent lecture.

Module Assessment

Type of Assessment				
Assessment Type	Learning Outcomes	Week	Day	Percentage

Total Percentage 100%

Formative Assessment and Feedback

Formative assessment will be predominantly provided through the weekly tutorials. These will explore concepts relevant to the previous week's lectures and more where appropriate, giving a better contextualisation of concepts covered during lectures.

The intermediate MOLE quizzes, which will have a minimum pass mark of 70% (but allow for multiple attempts) ought to give students individualised formative feedback at early stages of the course.

Additional seminars will be used to provide further feedback to students about their digestion of the material and concepts.

As mentioned, feedback on the coursework will be delivered to students prior to the final examination to ensure that there is time and scope to act on any comments received.

Recommended Reading

Book 1 - Highly Recommended

- Title:
Critical state soil mechanics
 - Author: [A. N. Schofield \(Andrew Noel\), 1930-](#)
 - Related Titles: Series: European civil engineering series
 - Publisher: McGraw-Hill, 1968
 - Subjects: [Soil mechanics](#)
 - Further Information: by Andrew Schofield and Peter Wroth.
 - Record Id: 21197246180001441
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Book 2 - Highly Recommended

- Title:
Constitutive and centrifuge modelling : two extremes : proceedings of the Workshop on Constitutive and Centrifuge Modelling: Two Extremes, Monte Verità, Switzerland, 8-13 July 2001
 - Author: [Workshop on Constitutive and Centrifuge Modelling: Two Extremes \(2001 : Monte Verità, Switzerland\)](#)
 - Other Contributors: [Sarah Springman](#)
 - Publisher: Lisse ; Exton, PA : Balkema, 2002
 - Identifier: ISBN 9058093611 (hd.bd.);ISBN 9789058093615
 - Format: xvii, 379 p. : ill. (some col.) ; 26 cm.
 - Subjects: [Soil mechanics -- Congresses](#); [Soils -- Testing -- Congresses](#); [Centrifuges -- Congresses](#)
 - Further Information: edited by Sarah Springman.
 - Record Id: 21194608780001441
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Book 3 - Highly Recommended

- Title:
Geomaterials : constitutive equations and modelling
- Uniform Title: Manuel de rhéologie des géomateriaux.
- Other Contributors: [Felix Darve](#); [Rhéologie des Géomateriaux \(Winter School\) \(1984 : Aussois\)](#)
- Publisher: Barking : Elsevier Applied Science, c1990
- Identifier: ISBN 1851663843;ISBN 9781851663842
- Format: xv,418p : ill. ; 23 cm.
- Notes: "Developed from a collection of papers presented at a French Winter School, Rhéologie des Géomateriaux, held from 28 November to 5 December 1984 in Aussois". Originally published in French by the Presses de l'école nationale des Ponts et Chaussées, Paris, in 1987.
- Subjects: [Rock mechanics](#); [Soil mechanics](#); [Rock mechanics](#); [Soil mechanics](#)
- Further Information: edited by Felix Darve.
- Language Note: Translation of Manuel de rhéologie des géomateriaux.

- Record Id: 21204644060001441

Critical State. Soil Mechanics. Andrew Schofield and Peter Wroth. Lecturers in Engineering at Cambridge University. Preface. This book is about the mechanical properties of saturated remoulded soil. It is written at the level of understanding of a final-year undergraduate student of civil engineering; it is material covered by standard textbooks such as Soil Mechanics in Engineering Practice by K. Terzaghi and R. B. Peck (Wiley 1948), Fundamentals of Soil Mechanics by D. W. Taylor (Wiley 1948) or Principles of Soil Mechanics by R. F. Scott (Addison-Wesley, 1963). In order to create a proper background for the critical state concept we have felt it necessary to emphasize certain aspects of continuum mechanics related to stress and strain.