UNIVERSITY OF WARWICK

Proposal Form for New or Revised Modules (MA1 - version 7 - April 2014)

Approval information	
Approval Type	☐ New module ☒ Revised module ☐ Discontinue module
Date of Introduction/Change	01/10/2018
If new, does this module replace another? If so, enter module code and title:	
If revised/discontinued, please outline the rationale for the changes:	Updated module aims, syllabus, bibliography and teaching and learning hours to reflect review of module by new module leader. One extraneous learning outcome removed, one other updated slightly.
Confirmation that affected departments have been consulted:	Changes were made in consultations between the School of Engineering and WMG.

Module Summary	
1. Module Code (if known)	ES96V
2. Module Title	Finite Element Methods for Tunnelling
3a. Lead department:	School of Engineering (100%)
3b. Teaching Split (if known):	100% Engineering
4. Name of module leader	Dr Mohammad Rezania
5. Level	UG: ☐ Level 4 (Certificate) ☐ Level 5 (Intermediate) ☐ Level 6 (Honours) PG: ☒ Level 7 (Masters) ☐ Level 8 (Doctoral) See Guidance Notes for relationship to years of study
6. Credit value(s) (CATS)	15

Module Summary	
7. Principal Module Aims	Finite element methods are widely used to determine the structural integrity of underground openings and their support systems. The first part of the module aims to introduce the fundamental principles of the mathematical modelling underpinning the finite element method for static analysis. The focus will be on the elastic-plastic constitutive model framework relevant to tunnelling/geotechnical problems. The students will then be taught how to use the method in practice and to critically assess and evaluate the results. The module aims to provide the user with skills in the application of commercial FEM software commonly used in underground design.
8. Principal Learning Outcomes	By the end of the module students should be able to: • Identify the significance and importance of finite element methods to the professional tunnel design engineer. • Utilise a theoretical understanding on the fundamentals of finite element methods for small displacement linear elastic analysis (statics) to solve a problem. • Solve problems using commercial FE software • Demonstrate how to develop good models and evaluate their performance, and how to interpret the numerical results in design
9. Timetabled Teaching Activities (summary)	15 hrs lectures, 15 hrs computer laboratories. **Total of 30 hours.**
10. Departmental Web-link	http://www2.warwick.ac.uk/fac/sci/eng/eso/modules/year4/es96v/
11. Other essential notes	The module is taught in a five-day intensive block (excluding Wednesday afternoon). Advice and feedback hours are available for answering questions on the module material. The module is available as a standalone CPD course for external attendees.
12. Assessment methods (summary)	2-hour Computer-based test 30% Coursework assignment 70%

For use by Strategic Planning and Analytics Office only - Do not fill in this section

Level	**JACS3 Code**		**Teaching Split**
			If not provided in 3b above
External Credit Level		**Scheme**	

Module Context

13. Please list all departments involved in the teaching of this module. If taught by more than one department, please indicate percentage split.

School of Engineering, 100%

14. Availability of module

Degree Code	Title	Study Year	C/OC/ A/B/C	Credits
H214	MSc Tunnelling and Underground Space FT	M1	C	15
H214	MSc Tunnelling and Underground Space PT	M1	OC	15
H214	MSc Tunnelling and Underground Space PT	M2	OC	15

15. Minimum number of registered students required for module to run

1

16. Pre- and Post-Requisite Modules

None

Module Content and Teaching

17. Teaching and Learning Activities *(totals for module – please see guidance)*

Module duration (weeks)	1
Lectures	15 hours
Seminars	
Tutorials	
Project Supervision	
Demonstration	
Practical Class/Workshops	15 hours computer laboratories
Supervised time in studio/workshop	
Fieldwork	
External visits	
Work based learning	
Placement	
Year abroad	
Other activity *(please describe): e.g. distance-learning, intensive weekend teaching etc.*	120 hours of guided independent learning

Module Content and Teaching

18. Assessment Method (Standard)

Type of assessment	**Length**	**% weighting**
Written Examinations		
Practical Examinations	2 hrs Computer-based test	30%
Assessed essays/coursework	Coursework assignment	70%
18a. Final chronological assessment *(please see guidance)*	Coursework assignment	

19. Methods for providing feedback on assessment.

In class Computer-based Test: Individual written feedback.
Coursework assignment: Individual written feedback.

20. Outline Syllabus

- Introduction to finite element method**:**
  - Matrix algebra
  - Linear equations
  - Numerical integration & approximation
  - Element & node
- One dimensional finite element analysis**:**
  - 1D example as basis problem
  - 1D example approximate solution
  - Total potential energy
  - Element & total strain energy
  - Minimum total potential energy
  - Discretisation & boundary conditions
- Continuum structures:
  - Plane Stress
  - Plane Strain
  - Axisymmetry
  - Theory of stress
    - Principal stresses
  - Theory of strain
  - Theory of elasticity
- Soil testing using direct shear box and triaxial apparatus:
  - Frictions and cohesion
  - Drained and undrained conditions
  - Interpretation of experimental data

Module Content and Teaching

- Elastic-plastic constitutive model framework:
    - Yield surface in 2D/3D
    - Normality & plastic flow
    - Soil compression
    - Basic elastic-plastic model predictions
        - under drained & undrained conditions
        - for normally consolidated to highly overconsolidated soils

- PLAXIS for 2D FE analysis of tunnels:
    - Main PLAXIS 2D functionalities
    - PLAXIS modelling workflow
    - Boundary conditions and mesh design
    - Results post-processing
    - Structural elements and soil-structure interactions
    - Practical use of PLAXIS 2D
        - Foundation analysis
        - Embankment analysis
        - Consolidation
    - Practical use of PLAXIS 2D tunnel designer
        - NATM tunnelling
        - Shield tunnelling
        - Dewatering

21. Illustrative Bibliography

- Zienkiewicz, Taylor and Zhu 2013. The Finite Element method, its basis and fundamentals (7th edition). Elsevier. Available as an e-book via http://encore.lib.warwick.ac.uk/iii/encore/record/C__Rb2821606
- Jacob Fish, T. Belytschko 2007. A first course in Finite Elements. Wiley. Available as an e-book via http://encore.lib.warwick.ac.uk/iii/encore/record/C__Rb2829814
- Wood, D.M., 1990. Soil behaviour and critical state soil mechanics. Cambridge University Press. Available as an e-book via http://encore.lib.warwick.ac.uk/iii/encore/record/C__Rb2784124
- Brinkgreve R.B.J., Engin E., Swolfs W.M., 2017. Plaxis 2017 Reference Manual. Plaxis: Delft, Netherlands. Available online at https://www.plaxis.com/support/manuals/plaxis-2d-manuals/.
- Cook, R.D., Malkus, D.S. and Plesha, M.E. 2002. Concepts and applications of Finite Element analysis (4th ed.). New York: Wiley. http://encore.lib.warwick.ac.uk/iii/encore/record/C__Rb1102599
- Jacob, P. and Goulding, L. 2002. An explicit finite element primer. Glasgow: NAFEMS. http://encore.lib.warwick.ac.uk/iii/encore/record/C__Rb2157597

22. Learning outcomes

Successful completion of the module leads to the learning outcomes. The learning outcomes identify the knowledge, skills and attributes developed by the module.

Module Content and Teaching
Learning Outcomes should be presented in the format "By the end of the module students should be able to..." using the table at the end of the module approval form:

Resources
23. List any additional requirements and indicate the outcome of any discussions about these.
The module is held in a computer room. Access to Plaxis 2D and Plaxis 3D commercial finite element analysis software is required, with sufficient licenses for each student to work individually. Access to the software from off site is required for part-time students to complete the assignment. All the provisions have been satisfactorily provided in the past.

Approval	
24. Module leader's signature	Dr Mohammad Rezania
25. Date of approval	25 April 2018
26. Name of Approving Committee (include minute reference if applicable)	School of Engineering and WMG Course and Module Approval Committee (CMAC), Minute 267-17/18
27. Chair of Committee's signature	Professor Gillian Cooke
28. Head of Department(s) signature	Professor David Towers

Examination Information		
A1. Name of examiner (if different from module leader)		
A2. Indicate all available methods of assessment in the table below		
% Examined	**% Assessed by other methods**	**Length of examination paper**
0%	**30% 2-hour Computer-based Test** **70% Coursework assignment**	**N/A**
A3. Will this module be examined together with any other module (sectioned paper)? If so, please give details below.		
No		
A4. How many papers will the module be examined by?	☐ 1 paper	☐ 2 papers
A5. When would you wish the exam take place (e.g. Jan, April, Summer)?		
A6. Is reading time required?	☐ Yes	☐ No
A7. Please specify any special exam timetable arrangements.		
N/A		
A8. Stationery requirements		
No. of Answer books?		
Graph paper?		
Calculator?		
Any other special stationery requirements (e.g. Data books, tables etc)?		
A9. Type of examination paper		
Seen?	☐ Yes	☐ No
Open Book?	☐ Yes	☐ No
Restricted?	☐ Yes	☐ No

Examination Information	
If restricted, please provide a list of permitted texts:	

LEARNING OUTCOMES		
(By the end of the module the student should be able to....)	**Which teaching and learning methods enable students to achieve this learning outcome? (reference activities in section 17)**	**Which summative assessment method(s) will measure the achievement of this learning outcome? (reference activities in section 18)**
Identify the significance and importance of finite element methods to the professional tunnel design engineer	Lectures, computer laboratories	Coursework assignment
Utilise a theoretical understanding on the fundamentals of finite element methods for small displacement linear elastic analysis (statics) to solve a problem	Lectures, computer laboratories	Computer-based test, Coursework assignment
Solve problems using commercial FE software	Lectures, computer laboratories	Computer-based test, Coursework assignment
Demonstrate how to develop good models and evaluate their performance, and how to interpret the numerical results in design	Lectures, computer laboratories	Computer-based test, Coursework assignment