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# Module 5R19: Earthquake Engineering [Draft]

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**Timing:** Lent Term

**Prerequisites:** This module is available to first year research students (PhD or MPhil).

**Structure:** 16 afternoon lectures, 1 hour each, two per week.

**Mode of Assessment:** Coursework.

## AIMS

The objective of this module is to introduce students to various aspects of earthquake engineering and structural dynamics. The focus will be on advanced methods of analysis allowed by building codes, and recent research developments that are relatively well-known to the academic community, but are still being implemented in practice. The module aims to provide understanding and analysis tools for the research context. The target audience is students whose research will incorporate some aspect of earthquake engineering, or students interested in gaining a more in-depth knowledge of the field.

## SYLLABUS

### 1) Fundamentals (2 Lectures)

- SDOF, MDOF systems
- Elastic response spectra
- Inelastic response spectra (ductility, R factor)
- Brief introduction to code-based procedures

### 2) Ground motion (Hazard) (2 Lectures)

- Fault rupture, seismic waves
- Earthquake Databases
- Earthquake Intensity Measures, structural demand measures (integration of these two)
- Near source and site effects (directivity, fling step, soil amplification)
- Vertical ground motion
- Ground motion prediction equations (GMPEs)
- Probabilistic Seismic Hazard Assessment (PSHA)
- Deaggregation

### 3) Nonlinear Static methods (2 Lectures)

- Acceleration-Displacement Response Spectrum (ADRS)
- Displacement modification techniques – FEMA 356
- Equivalent Linearization techniques – ATC 40
- N2 Method (Fajfar)
- Pushover (traditional, modal updating, multi-modal)

### 4) Dynamic methods (2 Lectures)

- Ground motion selection and scaling (spectral matching, SeismoMatch)
- Synthetic ground motions
- Incremental Dynamic Analysis
- Probabilistic Performance-Based Earthquake Engineering

## 5) Advanced Seismic Systems (2 Lectures)

- Buckling Restrained Brace (BRB) Solutions
- Base isolation
- Self-centring systems (Flag-shaped oscillators)
- Rocking systems
- Collapse and retrofit of masonry structures

## 6) Soil Dynamics and Soil Structure Interaction (6 Lectures)

- Soil as a two-phase medium and Non-linearity of soils
  - Shear strains and shear modulus degradation
  - Excess pore pressure generation and soil liquefaction
- Liquefaction potential of soils
  - Evaluation of CSR/CRR based on SPT and CPT testing
  - Liquefaction potential charts
  - Limitations of these methods
- Liquefaction remediation methods
  - In-situ densification techniques
  - Use of vertical drains/stone columns
- Dynamic soil-structure interaction
  - Simple discrete models
  - Structural response while including SSI effects
- Pile foundations in seismic areas
  - Additional lateral and axial loads
  - Mechanisms of load transfer
  - Pile foundations in liquefiable soils
- Dynamic earth pressures
  - Mononabe and Okabe equations
  - Retaining walls under earthquake loading
  - Dynamic earth pressures on basement walls

## COURSEWORK AND ASSESSMENT

Students will submit three pieces of investigatory coursework (**30 marks per coursework item**) and one presentation (**10 marks**).

### A) Examples of coursework assignments:

1. SDOF systems and Ground motions
  - short project/investigation with elastic and inelastic response spectra
  - short project/investigation involving ground motion selection, processing, scaling, and evaluation of intensity measures.
2. Computational analysis including nonlinear response
  - Conduct nonlinear static analysis using one of the methods introduced in lectures
  - Conduct nonlinear dynamic analysis using a backbone curve (Matlab)
3. Soil-structure interaction
  - Shallow foundation design based on EC8
  - Seismic Pile foundation design
  - Dynamic earth pressure calculations on a retaining wall

### B) Presentation: Each student presents a research paper relevant to the course content

- 10 minute talk and 5 minutes questions

## REFERENCES

- Dynamics of Structures, A. Chopra, Prentice Hall (2000)  
Advances in Performance-Based Earthquake Engineering, Fardis (editor), Springer (2010)  
Probabilistic Performance-Based Seismic Design, CEB-FIB Technical Report (2012)  
Geotechnical Earthquake Engineering, S. L. Kramer, Prentice Hall (1996)  
Seismic design of Buildings to Eurocode 8, A.Y. Elghazouli (editor), Spon Press (2009).