

Earthquake Engineering

Course Structure

Year : I								Part I
Teaching Schedule				Examination Scheme			Total	Remarks
S.N.	Course Code	Course title	Credit	Assessment Marks	Final			
					Duration Hours	Marks		
1	ENCEEQ 501	Solid Mechanics	4	40	3	60	100	
2	ENCEEQ 502	Theory of Vibrations	4	40	3	60	100	
3	ENCEEQ 503	Engineering Seismology	4	40	3	60	100	
4	ENCEEQ 504	Geotechnical Earthquake Engineering	4	40	3	60	100	
Total			16	160		240	400	

Year : I								Part II
Teaching Schedule				Examination Scheme			Total	Remarks
S.N.	Course Code	Course title	Credit	Assessment Marks	Final			
					Duration Hours	Marks		
1	ENCEEQ 551	Seismic Resistant Design of Structures	4	40	3	60	100	
2	ENCEEQ 552	Finite Element Methods	4	40	3	60	100	
3	ENCEEQ 561-563	Elective- I	4	40	3	60	100	

4	ENCEEQ 571-574	Elective II	4	40	3	60	100	
Total			16	160		240	400	

Year : II					Part I			
Teaching Schedule				Examination Scheme			Total	Remarks
S. N.	Course Code	Course title	Credit	Assessment Marks	Final			
					Duration Hours	Marks		
1	ENCEEQ 611-614	Elective -III	4	40	3	60	100	
2	ENCEEQ 621-624	Elective -IV	4	40	3	60	100	
3	ENCEEQ 601	Research Project	4	40	3	60	100	
Total			12	120		180	300	

Year : II					Part II			
Teaching Schedule				Examination Scheme			Total	Remarks
S. N.	Course Code	Course title	Credit	Assessment Marks	Final			
					Duration Hours	Marks		
1	ENCEEQ 651	Research Thesis	16	100			100	

List of Electives

Elective- I:

- a. Computer application for Earthquake Engineering Simulations (ENCEEQ 561)
- a. Non Linear Analysis of Structures (ENCEEQ 562)
- b. Research Methodology (ENCEEQ 563)

Elective -II:

- b. Structural Health Monitoring (ENCEEQ 571)
- c. Seismic Resistant Design of Sub-structures (ENCEEQ 572)
- d. Design and Testing of Seismic Resistant Masonry (ENCEEQ 573)
- e. Disaster Risk Evaluation, Policies and Management (ENCEEQ 574)

Elective -III:

- a. Advanced Optimization Techniques in Earthquake Engineering (ENCEEQ 611)
- b. Performance Based Design of Structures (ENCEEQ 612)
- c. Design of Industrial Structures (ENCEEQ 613)
- d. Seismic Risk Assessment and Retrofitting Techniques (ENCEEQ 614)

Elective -IV:

- a. Application of AI tools in Earthquake Engineering (ENCEEQ 621)
- b. Structural Control and Base Isolation (ENCEEQ 622)
- c. Design of Bridges (ENCEEQ 623)
- d. Earthquake Engineering Laboratory (ENCEEQ 624)

Thesis

M. Sc. Thesis In Earthquake Engineering

Potential Research Domain for Thesis Work:

- Seismic Hazard Assessment
- Structural Dynamics and Earthquake-resistant Design and Optimization
- Soil-Structure Interaction
- Seismic Retrofitting and Rehabilitation
- Performance-Based Seismic Design
- Seismic Risk and Loss Assessment
- Earthquake Early Warning Systems
- Numerical Modeling and Simulation
- Seismic Ground Motion Analysis

Computer Application for Earthquake Engineering Simulations
ENCEEQ 561

Lecture: 3 hrs.

Tutorial: 0 hr.

Practical: 1 hrs.

Year: I

Part: II

Course Objectives:

By the end of this course, students will be proficient in using platforms like C++ for object-oriented programming in earthquake engineering simulations. They will learn to utilize robust software such as OpenSees for selecting and adding new elements, algorithms, integrators, and solvers. Additionally, students will gain expertise in pre- and post-processing using MATLAB, enabling them to display simulation results comprehensively with extended links and flexible graphical interfaces. This skill set is crucial for effective earthquake engineering analysis and design.

Course Contents:

1. C++ Basics

(4 hours)

- 1.1. Features of C++
- 1.2. Setting up C++ development environment
- 1.3. Syntax, comments, keywords, identifiers
- 1.4. Variables (Global and local) and constants
- 1.5. Data types
- 1.6. Operators
- 1.7. Input/output
- 1.8. Control statements
- 1.9. Functions
- 1.10. Pointers and references
- 1.11. Arrays, strings, structures and unions
- 1.12. Dynamic memory management

2. Object-Oriented Programming in C++

(8 hours)

- 2.1. Classes and Objects
- 2.2. Modifiers
- 2.3. Friend class and function
- 2.4. Constructors and destructors
- 2.5. Static Data members and static member functions
- 2.6. 'this' pointer in C++
- 2.7. Difference between structure and class
- 2.8. Virtual functions
- 2.9. Inheritance and polymorphism
- 2.10. Encapsulation and abstraction
- 2.11. Function and operator overloading
- 2.12. Files and streams

3. Python (6 hours)

- 3.1. Introduction
- 3.2. Python and PyCharm installation
- 3.3. Variables
- 3.4. Receiving input and displaying output
- 3.5. Type conversion
- 3.6. Strings
- 3.7. Arithmetic operators and operation precedence
- 3.8. Comparison and logical operators
- 3.9. IF statement
- 3.10. WHILE Loops
- 3.11. FOR loops
- 3.12. Lists and list methods

4. Getting Started with OpenSees (7 hours)

- 4.1. Introduction
- 4.2. Download and run OpenSees
- 4.3. User and developer interface
- 4.4. Tcl script and OpenSees Navigator
- 4.5. Problem definition
- 4.6. Model builder
- 4.7. Nodes
- 4.8. Materials and elements
- 4.9. Geometric transformation
- 4.10. Recorders
- 4.11. Loads and analysis

5. OpenSees Commands and Post-Processing (10 hours)

- 5.1. Modeling commands (Domain, Node, Element, Constraint, Load Pattern)
- 5.2. Analysis commands (Constraint Handler, DOF_Numberer, Integrator, Algorithm, System of Equation/Solver, Convergence test)
- 5.3. Output commands (Recorder, Print, LogFile, RealTime Output Commands)
- 5.4. Misc commands (Response, Tags, Coordinates, Velocity, Acceleration, Eigenvector, etc.)
- 5.5. Database commands (FileDataStore, Save, Restore)
- 5.6. Post-processing in Matlab, OpenSees, other FEM-based software

6. MATLAB (10 hours)

- 6.1. Introduction and documentation
- 6.2. Build and run MATLAB statements
- 6.3. Matrices and Arrays
- 6.4. Data types
- 6.5. Operators and elementary operations
- 6.6. Loops and conditional statements
- 6.7. Text files, spreadsheets, and other file formats
- 6.8. Data cleaning, smoothing, grouping

- 6.9. Interpolation and optimization
- 6.10. Numerical integration and differential equations
- 6.11. Fourier transforms, convolution, and digital filtering
- 6.12. Sparse matrices, reordering algorithm, iterative methods, and triangulation
- 6.13. Graphics and programming in MATLAB
 - 6.13.1. 2D and 3D plots, discrete, continuous, volume data
 - 6.13.2. Formatting and annotation, images, graphic objects
 - 6.13.3. Programming utilities

Evaluation Schemes:

a. Internal Examination

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Examination

There will be 6 units of questions carrying marks as provided in the following table. The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Units	Chapters	Marks
1	1	8
2	2	12
3	3	8
4	4	5
5	5	15
6	6	12
Total		60

References:

1. J.R. Hubbard, **Programming with C++** (2nd edition), McGraw-Hill, 2021.
2. S. Mazzoni, F. McKenna, M. H. Scott, and G. L. Fenves, **OpenSees command language manual**, Pacific earthquake engineering research (PEER) center, 264(1), 137-158, 2006.
3. **MATLAB® 7, Getting Started Guide**, Mathworks, 1984
4. B. R. Hunt, R. L. Lipsman, and J.M. Rosenberg, **A guide to MATLAB: for beginners and experienced users**, Cambridge university press, 2014.
5. C. Fehily, **Python**, Peachpit Press, 2002.
6. Benjamin Dicken, **PyFlo – A Free, Interactive Guide to Python Programming**, 2023. pyflo.net

Disaster Risk Evaluation, Policies and Management
ENCEEQ 574

Lecture: 3 hrs.

Year: I

Tutorial: 1 hr.

Part: II

Practical: 0 hr.

Course Objectives:

This course provides an in-depth examination of disaster risk evaluation methodologies, policies, and management strategies. Students will explore theoretical frameworks, practical tools, and case studies to understand the complexities of disaster risk, policy formulation, and effective management approaches. Emphasis will be placed on interdisciplinary perspectives, incorporating insights from fields such as geography, sociology, economics, and public policy.

Course contents:

1. Introduction to disaster Risk Management

(8 hours)

- 1.1. Statement of optimization problem
- 1.2. Definitions and conceptual frameworks
 - 1.2.1. Technology, environment and society
 - 1.2.2. Natural resource
 - 1.2.3. Global change
- 1.3. Disaster risk reduction and management terminology
- 1.4. Disaster management cycle
 - 1.4.1. Mitigation
 - 1.4.2. Preparedness
 - 1.4.3. Prevention
 - 1.4.4. Emergency response
 - 1.4.5. Recovery
 - 1.4.6. Construction

2. Understanding of disaster risk

(8 hours)

- 2.1. Risk Assessment methodologies
- 2.2. Hazard, vulnerability, and risk assessment
- 2.3. Definition, concept, and analysis of risk
 - 2.3.1. Quantitative risk analysis
 - 2.3.2. Qualitative risk analysis

3. Earthquake disaster recovery and reconstruction

(10 hours)

- 3.1. Risk Assessment methodologies
- 3.2. Post-disaster recovery planning
- 3.3. Infrastructure reconstruction and rehabilitation
- 3.4. Resilience-building strategies for communities

4. Disaster Risk Management and Planning (8 hours)

- 4.1. Definition
- 4.2. Types of DRM plan
 - 4.2.1. Risk management strategies and plans
 - 4.2.2. Contingency plans
 - 4.2.3. Disaster response plan
 - 4.2.4. Disaster recovery planning
 - 4.2.5. Business continuity planning
- 4.3. Early warning systems: components, structure, and operation

5. Information and Communication for DRM (10 hours)

- 5.1. Role of science and technology in Disaster Risk Reduction/Management
- 5.2. ICT solutions for DRM: Databases, Web application, Geographic Information System (GIS), Sensors, Radio broadcasts, Mobile phones, Social media, Software, Data standards, Lifecycle
- 5.3. Use of frontier technologies in DRR/M
 - 5.3.1. Unmanned Aerial Vehicles (UAV)
 - 5.3.2. Virtual Reality (VR)
 - 5.3.3. Artificial Intelligence (AI)
 - 5.3.4. Augmented Reality (AR)

6. Disaster Risk Reduction and Management Strategies (12 hours)

- 6.1. Milestone of disaster risk reduction
 - 6.1.1. International decade for Natural Disaster Reduction,
 - 6.1.2. Yokohama Strategy and Plan of Action for a Safer World,
 - 6.1.3. Guidelines for Reducing Flood Losses,
 - 6.1.4. Hyogo Declaration and Hyogo Frameworks of Action 2005-2015,
 - 6.1.5. International Day for Disaster Reduction,
 - 6.1.6. Sendai Declaration and Sendai Framework for Disaster Risk Reduction
- 6.2. Millennium development goals and sustainable development goals
- 6.3. Institution and legal system of DRM in Nepal
 - 6.3.1. Natural Calamity (Relief) Act, 1982

6.3.2. Disaster Risk Reduction and Management (DRRM) Act, 2017

6.3.3. National Policy for Disaster Risk Reduction (2018)

7. Disaster Risk Reduction and Management Strategies

(4 hours)

7.1.1. Earthquake-induced secondary hazards (e.g. Tsunamis, landslides)

7.1.2. Technological innovation for early warning and monitoring

7.1.3. Climate change and its impact on seismic risk

Evaluation Schemes:

a. Internal Examination

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Examination

There will be 7 units of questions carrying marks as provided in the following table. The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Units	Chapters	Marks
1	1	10
2	2	10
3	3	8
4	4	8
5	5	8
6	6	10
7	7	6
Total		60

References:

1. Bass, S., Ramasamy, S., Pyyck, J.D.D., and Battisa, F., , **Disaster risk management systems analysis**, A guidebook, Food and Agriculture Organization of the United Nations, 2008, 90p.
2. Ranke, U., **Natural Disaster Risk Management: Geoscience and Social Responsibility**, Springer, 2016, 513p.
3. Shi, P., **Disaster Risk Science**, Springer, (2019), 766p.
4. **National Policy for Disaster Risk Reduction**, Ministry of Home Affairs, The Government of Nepal, 2018, 40p.
5. **Disaster Risk Reduction and Management act**, Ministry of Home Affairs, Government of Nepal, 2017, 27p.
6. Bhandari, D., Neupane, S., Hayes, P., Regmi, B., and Marker, P., **Disaster risk reduction and management in Nepal: Delineation of roles and responsibilities**, Oxford Policy Management, 2020.

7. Mitchell, T., Jones, L., Lovell, E. and a Comba, E., **Disaster Risk Management in Post-2015 Development Goals: Potential Targets and Indicators**, 2013, Overseas Development Institute, ISBN 978-1-909464-31-5
8. **ICT for Disaster Risk Management**, (2020), United Nations, 154p
9. Rossetto, T., & Elnashai, A., **Earthquake Engineering for Urban Risk Reduction**, 2010.

Finite Element Method
ENCEEQ 552

Lecture: 3 hrs.

Year: I

Tutorial: 1 hr.

Part: II

Practical: 0 hr.

Course Objectives:

This course combines the fundamental ideas of solid mechanics with numerical solution of the large and complicated engineering problems using polynomials. Complicated geometry is discretized into simple and regular shapes. Physical problems will be converted into mathematical model and combined with constitutive relation develops stiffness matrices and solve with iterative procedures.

Course Contents:

- 1. Introduction (2 hours)**
 - 1.1. Basic concepts
 - 1.2. History of Finite Element Method (FEM)
 - 1.3. Introduction to other Meshfree Methods: Boundary Element Method (BEM); Discrete Element Method (DEM); Smoothed Particle Hydrodynamic Method (SPH)
 - 1.4. Suitability of methods
 - 1.5. FEM versus other numerical methods
- 2. Basic Elasticity (2 hours)**
 - 2.1. Introduction
 - 2.2. Equations of equilibrium
 - 2.3. Constitutive law
 - 2.4. Plane stress and strain problems
- 3. Matrix Displacement Formulations (5 hours)**
 - 3.1. Matrix displacement equations
 - 3.2. System of linear equations
 - 3.3. Banded matrix
 - 3.4. Iterative methods for matrix solution
- 4. Variational Methods (6 hours)**
 - 4.1. Introduction
 - 4.2. Potential energy approach
 - 4.3. Rayleigh Ritz method
 - 4.4. Galerkin's method of weighted residuals
- 5. Shape Functions (6 hours)**
 - 5.1. Shape functions using polynomials
 - 5.2. Shape function by Lagrange polynomial
 - 5.3. Shape function for serendipity element

5.4. C_0 and C_1 elements

6. Formulation of 1D Elements (6 hours)

- 6.1. Spring element
- 6.2. Bar element
- 6.3. Beam element
- 6.4. Beam and frame analysis

7. Formulation of 2D Elements (8 hours)

- 7.1. Constant strain triangle
- 7.2. Quadrilateral elements
- 7.3. Numerical integration
- 7.4. Higher order elements

8. Formulation of 3D Elements (8 hours)

- 8.1. Tetrahedron elements
- 8.2. Hexahedron elements
- 8.3. Joint elements
- 8.4. Axisymmetric elements

9. Plates and Shell Elements (8 hours)

- 9.1. Introduction to plate theory
- 9.2. Thin plate-Kirchoff plate element
- 9.3. Thick plate – Mindlins plate element
- 9.4. Formulation of shell elements

10. Structural Vibration and Dynamics (6 hours)

- 10.1. Consistent mass matrices
- 10.2. Dynamic equilibrium equations
- 10.3. Mass matrices for spring, bar truss, beam and area elements
- 10.4. Natural frequencies
- 10.5. Solution of multi-degree of freedom problems

11. Introduction to Solution of Non-linear Equations (5 hours)

- 11.1. Types of non-linearities; materials and geometric
- 11.2. Stability of numerical solutions
- 11.3. Newton-Raphson method

Evaluation Schemes:

a. Internal Examination

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Examination

There will be 7 units of questions carrying marks as provided in the following table. The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Units	Chapters	Final Exam Marks
1	1,2,3&4	7
2	5	7
3	6	9
4	7	10
5	8	10
6	9	10
7	10 & 11	7
Total		60

References:

1. O. C. Zienkiewicz, R. L. Taylor, **The Finite Element Method, Vol. 1, The Basis**, Elsevier, 2000.
2. O. C. Zienkiewicz, R. L. Taylor, **The Finite Element Method, Vol. 2, Solid Mechanics**, Elsevier, 2000.
3. O. C. Zienkiewicz, R. L. Taylor, **The Finite Element Method, Vol. 3, Fluid Dynamics**, Elsevier, 2000.
4. D. V. Huttan, **Fundamentals of Finite Element Analysis**, TATA McGRAW-HILL, 2004.
5. J.N. Reddy, **An Introduction to the Finite Element Method**, McGRAW-HILL, 2005.
6. S. S. Bhavikatti, **Finite Element Analysis**, NEW AGE INTERNATIONAL PUBLISHERS, 2005.
7. S. Rajasekaran, **Finite Element Analysis in Engineering Design**, S. CHAND, 2008.
8. T. R. Chandrapatla and A. D. Belegundu, **Introduction to Finite Elements in Engineering**, PHI, 2000.
9. R.D. Cook, D. S. Malkus and M. E. Plesha, **Concepts and Applications of Finite Element Analysis**, JOHN WILEY & SONS, 2000.
10. C. S. Krishnamurthy, **Finite Element Analysis- Theory and Programming**, TATA McGRAW-HILL, 2000.
11. G. Beer, **Programming The Boundary Element Method, An Introduction for Engineers**, J Wiley, 2001
12. A. Munjiza, **The combined Finite-Discrete Element Method**, J Wiley, 2004
13. S. Li and W. K. Liu, **Meshfree Particle Methods**, Springer, 2004

Non-Linear Analysis of Structures
ENCEEQ 562

Lecture: 3 hrs.

Tutorial: 1 hr.

Practical: 0 hr.

Year: I

Part: II

Course Objectives:

This course aims to equip students with skills to solve nonlinear differential equations using weighted residual methods and various numerical techniques. It provides understanding of nonlinear behavior in trusses and beams, techniques for solving dynamic nonlinear problems, and knowledge of nonlinearities and material constitutive laws.

Course Contents:

- 1. Introduction to Non-Linear Analysis of Structures (2 hours)**
 - 1.1. Introduction
 - 1.2. Sources of non-linearity and nonlinear problems
 - 1.3. Need of nonlinear analysis of structures
 - 1.4. Challenges of nonlinearities in civil engineering

- 2. Nonlinearity and Some Simple Material Constitutive Laws (6 hours)**
 - 2.1. Bilinear stress-strain relationship
 - 2.2. Cyclic behavior and different hardening models
 - 2.3. Model of Menegotto-Pinto for steel reinforcement
 - 2.4. Material laws for concrete

- 3. Non-Linear Solution Techniques (16 hours)**
 - 3.1. Introduction, need and types of nonlinear solution techniques
 - 3.2. Incremental load method
 - 3.3. Single step direction iteration method
 - 3.4. Direct iteration with load step
 - 3.5. Newton-Raphson method
 - 3.6. Modified Newton-Raphson method
 - 3.7. Write computer program to compare each solution technique

- 4. Method of Weighted Residuals (10 hours)**
 - 4.1. Introduction
 - 4.2. Collocation method
 - 4.3. Sub-domain method
 - 4.4. Least squares method
 - 4.5. Galerkin method

5. Error Estimation and Convergence (6 hours)

- 5.1. Source of error
- 5.2. Ill-conditioning and its examples
- 5.3. Structural vision of ill-conditioning
- 5.4. Residuals and convergence

6. Non-Linear Behavior of Structural Members (8 hours)

- 6.1. Nonlinear truss element
- 6.2. Nonlinear beam element
- 6.3. Nonlinear behavior for plate and shell elements

7. Solutions of Dynamic Non-Linear Problems (12 hours)

- 7.1. Solving the equation of motion
- 7.2. Modal decomposition
- 7.3. Wilson- θ method
- 7.4. Newmark Beta method
- 7.5. Houbolt method
- 7.6. Park Stiffly stable method
- 7.7. Write program to solve dynamic nonlinear problem

Evaluation Schemes:

a. Internal Examination

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Examination

There will be 6 units of questions carrying marks as provided in the following table. The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Units	Chapters	Marks
1	1&2	4
2	3	15
3	4	15
4	5	3
5	6	8
6	7	15
Total		60

References:

- 1. Cook, R. D., Malkus, D. S., Plesha, M. E. and Witt, R. J. (2002) **Concepts and applications of finite element analysis**, 4th Ed, John Wiley & Sons, New York.

2. Grandin, H. (1991) **Fundamentals of the Finite Element Method**, Waveland Press.
3. Bathe, K. J. (1996) **Finite element procedures**, Prentice Hall, New York.
4. Chopra, A. K. (2001) **Dynamics of Structures: Theory and Applications to Earthquake Engineering**, 2nd Ed, Prentice-Hall, NJ.
5. McKenna F. and Fenves G. L. (2001) **OpenSees manual** PEER Center (<http://OpenSees.berkeley.edu>)

Research Methodology
ENCEEQ 563

Lecture: 3 hrs.

Tutorial: 1 hr.

Practical: 0 hr.

Year: I

Part: II

Course Objectives:

This course provides foundational knowledge and practical skills in research methodology tailored for engineering contexts. Emphasizing application over theory, it equips students with essential tools for data collection, analysis, and writing, preparing them for effective research endeavors in their academic and professional pursuits.

Course Contents:

- 1. Introduction (2 hours)**
 - 1.1. Introduction to research
 - 1.2. Characteristics of research
 - 1.3. Classification of research
 - 1.4. Basic research process
 - 1.5. Ethical issues

- 2. Problem Formulation (8 hours)**
 - 2.1. Literature review
 - 2.2. Problem definition
 - 2.3. Research question
 - 2.4. Research objectives
 - 2.5. Variable identification
 - 2.6. Hypothesis formulation

- 3. Research Design (8 hours)**
 - 3.1. Elements of research design
 - 3.2. Qualitative and quantitative research designs
 - 3.3. Descriptive, comparative, correlational research designs
 - 3.4. Casual-comparative, exploratory, and experimental research design
 - 3.5. Case study research design
 - 3.6. Common sources of errors

- 4. Data Collection (8 hours)**
 - 4.1. Data types and sources
 - 4.2. Sampling: design, size, theory, distribution
 - 4.3. Data collection methods

- 5. Data Analysis (12 hours)**
 - 5.1. Data processing and classification

- 5.2. Descriptive analysis
- 5.3. Special probability distributions
- 5.4. Inferential analysis
- 5.5. Presentation of data and results

6. Inferential Analysis and Statistical Tools (14 hours)

- 6.1. Estimation theory and interval estimation
- 6.2. Hypothesis testing: parametric and non-parametric tests
- 6.3. Hypothesis testing using statistical tools
- 6.4. Regression
- 6.5. Regression analysis using statistical tools

7. Writing Thesis and Research Articles (8 hours)

- 7.1. Basic contents
- 7.2. General format
- 7.3. Writing procedure
- 7.4. Referencing

Evaluation Schemes:

a. Internal Examination

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Examination

There will be 7 units of questions carrying marks as provided in the following table. The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Units	Chapter	Marks
1	1	2
2	2	8
3	3	6
4	4	12
5	5	8
6	6	16
7	7	8
Total		60

References:

1. Kothari, C. R., and Garg, G., **Research Methodology: Methods and Techniques**, New Age International, 3rd Edition, 2014.
2. Kumar, R., **Research Methodology: A Step-by-Step Guide for Beginners**, 3rd Edition. SAGE Publications, 2011.
3. Singh, Y. K., **Fundamental of research methodology and statistics**, New Age International, 2006.

Design and Testing of Seismic Resistant Masonry Structure
ENCEEQ 573

Lecture: 3 hrs.

Year: II

Tutorial: 0 hr.

Part: I

Practical: 1 hr.

Course Objectives:

The basic objective is to provide the insight into the concepts and theories on various masonry units, assemblages and structures. It also gives insight to the testing methods of masonry units, wallets and simulation techniques to evaluate the seismic response of masonry wallets and structures.

Course Contents:

1. Fundamentals of Masonry Structures

(6 hours)

- 1.1. History of masonry structures in ancient and modern times
- 1.2. Nature of masonry structures
- 1.3. Masonry units, major constituents of masonry units
- 1.4. Properties of masonry materials and units
- 1.5. Testing of masonry units
- 1.6. Masonry mortar: Constituents of mortar, different types of mortars and selection criteria
- 1.7. Grout and its properties
- 1.8. Properties of masonry assemblage
- 1.9. Masonry Typology
 - 1.9.1. Unreinforced masonry
 - 1.9.2. Reinforced masonry
 - 1.9.3. Pre-stressed masonry
- 1.10. Aging effects and durability of materials
- 1.11. Material selection criteria: Availability, acceptability and affordability
- 1.12. Types of masonry structures:
 - 1.12.1. Load bearing walls,
 - 1.12.2. Infill masonry,
 - 1.12.3. Confined masonry
- 1.13. Elements of masonry structures
- 1.14. Structural elements: walls, piers, spandrels and arches
- 1.15. Sources of weakness in masonry structures
- 1.16. Historical perspective on seismic design of masonry structures

2. Seismic Behavior of Masonry Structures

(7 hours)

- 2.1. Failure mechanism due to gravity loads
- 2.2. Effect of eccentric loading on masonry wall
- 2.3. Effect of openings in masonry shear wall
- 2.4. Factors affecting the seismic performance of masonry buildings

- 2.4.1. Geometry
- 2.4.2. Material properties
- 2.4.3. Construction quality
- 2.5. In-plane behavior of masonry wall
- 2.6. Out-of-plane behavior of masonry wall
- 2.7. Failure mechanisms of masonry during earthquake
- 2.8. Failure modes of URM under lateral loads
 - 2.8.1. Rocking failure mode
 - 2.8.2. Sliding failure mode
 - 2.8.3. Toe crushing type failure mode
 - 2.8.4. Diagonal tension failure of piers
 - 2.8.5. Spandrel failure
 - 2.8.6. Shear and flexure failure of piers
- 2.9. Loads resisting mechanisms for masonry walls
 - 2.9.1. Flexural tensile strength
 - 2.9.2. Compressive strengths
- 2.10. Flexural behavior of URM walls
 - 2.10.1. Vertical flexure
 - 2.10.2. Horizontal flexure
 - 2.10.3. Two-way flexure
- 2.11. Arching actions in walls
- 2.12. Rigidity of masonry pier with different boundary conditions
- 2.13. Code provisions for masonry wall design (e.g., Eurocode 8, ASCE 7, Indian Standards)

3. Seismic Analysis and Design of Masonry Structures

(10 hours)

- 3.1. Performance of masonry structures during past earthquakes
- 3.2. Design philosophy and design principles
- 3.3. Role of regular and irregular buildings
- 3.4. Role of geometric configuration in lateral force resisting behavior
- 3.5. Role of load path regularity in lateral force resisting behavior
- 3.6. Role of mass and rigidity regularity in lateral force resisting behavior
- 3.7. Lateral load resisting systems in masonry structures
- 3.8. Effect of floor diaphragms in lateral load distribution
 - 3.8.1. Flexible floor diaphragms Horizontal flexure
 - 3.8.2. Semi-rigid floor diaphragms
 - 3.8.3. Rigid floor diaphragms
- 3.9. Effect of roof in lateral load distribution and resistant
- 3.10. Modes of failure of masonry structures
- 3.11. Behavior of masonry members: Shear and flexure; combined axial and bending actions
- 3.12. Analysis of masonry structures for in-plane loading
- 3.13. Analysis of masonry structures for out-of-plane loading
- 3.14. Masonry modeling: Heterogeneous models, homogeneous models, damage model for block units and mortar
- 3.15. Concept and importance of box effect

3.15.1. Methods of creating box effect

3.15.2. Vertical and horizontal bands

3.15.3. Corner stitches

3.16. Design of bands, bandages, splints and ties

3.17. Ductility in masonry walls and structures

3.18. Code provisions for masonry analysis, design and detailing

4. Confined and Reinforced Masonry

(6 hours)

4.1. Historical background

4.2. Methods of analysis and design

4.3. Code provisions

4.4. Need of reinforcement in masonry structures

4.5. Modes of failure of reinforced masonry

4.6. Ductility of reinforced masonry walls and structures

4.7. Flexural and shear strength of reinforced masonry

4.8. Code provisions for reinforced masonry analysis, design and detailing

5. Modern Seismic Resistance Design Techniques

(6 hours)

5.1. Modern materials for masonry construction

5.1.1. High-strength mortar

5.1.2. Engineered masonry units

5.2. Innovative construction techniques

5.2.1. Prefabricated masonry panels

5.2.2. Pre-stressed masonry panels

5.2.3. 3D printed masonry walls

5.3. Advanced modeling techniques:

5.3.1. Finite element analysis

5.3.2. Nonlinear dynamic analysis

5.4. Optimization of Masonry panels

5.4.1. Panel topology optimization

5.4.2. Panel thickness optimization

5.4.3. Panel size optimization

5.4.4. Panel shape optimization

5.5. Performance-based seismic design

6. Testing of Masonry Materials and Structures

(10 hours)

6.1. Testing of masonry units for strength, water absorption, and efflorescence.

6.2. Tests to evaluate the workability of mortar and its strength.

6.3. Tensile strength of reinforcing rebar, anchor rods.

6.4. Tests to evaluate compressive strength, modulus of elasticity, shear strength and diagonal tensile test of masonry wallets

6.5. Non-destructive tests to evaluate the material strength

Practical

(15 hours)

1. Testing of masonry units for strength, water absorption, and efflorescence.

2. Tests to evaluate the workability of mortar and its strength.
3. Tensile strength of reinforcing rebar, anchor rods.
4. Tests to evaluate compressive strength, modulus of elasticity and shear strength of masonry walls.
5. Non-destructive tests to evaluate the material strength.
6. Solve a URM wall problem manually and using FEA software.
7. Model the building, using FEA software and manually.

Evaluation Schemes:

a. Internal Examination

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Examination

There will be 6 units of questions carrying marks as provided in the following table. The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Units	Chapters	Marks
1	1	8
2	2	12
3	3	15
4	4	5
5	5	8
6	5	12
Total		60

References:

1. Drysdale, R.G., Hamid, A.A., Baker L.R, **Masonry Structures Behavior and Design**, Prentice Hall, Englewood Cliff, New Jersey 07632, 1994.
2. Tomazevic, M., **Earthquake Resistant Design of Masonry Buildings**, Imperial College Press, 57 Shelton Street, London WC2H 9HE, 2006.
3. **Seismic Vulnerability Evaluation Guidelines for Private and Public Buildings**, Department of Urban Development and Building Construction (DUDBC), Government of Nepal, 2011 (Part I & II).
4. Paulay, T., and Priestley, M. J. N., **Seismic Design of Reinforced Concrete and Masonry Buildings**. John Wiley & Sons, Inc., New York, 1992.
5. Hendry, W., Sinha, B. P., Davies, S. R., **Design of Masonry Structures**. E & FN Spon, London UK, 1997.
6. Sahlin, S., **Structural Masonry**. Prentice Hall, Englewood Cliffs, New Jersey, 1971.
7. Hendry, W., **Structural Masonry**. Macmillan, Houndmills, Basingstoke, 1998.
8. Arya, A., Boen, T., Ishiyama, Y., Martemianov, A., Meli, R., Scawthorn, C., Vargas, J. and Yaoxian, Y., **Guidelines for earthquake resistant non-engineered construction**, 1986/2010.

9. **Nepal National Building Code, NBC 105: 2020, Seismic Design of Buildings in Nepal**, Department of Urban Development and Building Construction, Nepal.
10. **Nepal National Building Code (NBC) 109: 1994 on Unreinforced Masonry**.
11. **IS 1893: 2016, Criteria for Earthquake Resistant Design of Structures**, Bureau of Indian Standards, New Delhi.
12. **IS 1905 IS 1905: 1987, Code of Practice for Structural Use of Unreinforced Masonry**, Bureau of Indian Standards, New Delhi.
13. **Assessment and Improvement of Structural Performance of the Buildings in Earthquakes**, NZSEE, 2006.
14. **FEMA 310, Handbook for the Seismic Evaluation of Buildings**, Federal Emergency Management Agency, USA, 1998.
15. **ASCE/SEI 41-17, Seismic Evaluation and Retrofitting of Existing Buildings**, Reston, Virginia, 2017.

Seismic Resistant Design of Structures
ENCEEQ 551

Lecture: 3 hrs.

Year: I

Tutorial: 1 hr.

Part: II

Practical: 0 hr.

Course Objectives:

By the end of this course, students will have a fundamental understanding of earthquake design requirements and the behavior of structures under ground motion, essential for rational analysis and design against seismic excitations. They will gain basic knowledge on how to analyze and design structures to withstand earthquakes and resist strong ground motions, ensuring structural integrity and safety in seismic-prone areas.

Course Contents:

- 1. Introduction (4 hours)**
 - 1.1. Behavior of structures under earthquakes
 - 1.2. Theories and criteria of seismic design
 - 1.3. Basic requirements for seismic resistant structures

- 2. Response of Structures (20 hours)**
 - 2.1. Review of single degree of freedom system to support movement.
 - 2.2. Mode shapes and frequencies of multi degrees of freedom system
 - 2.3. Normal mode theory
 - 2.4. Mode participation factors
 - 2.5. Effective model mass
 - 2.6. Pseudo static force in each mode of vibration due to earthquake.
 - 2.7. Response spectrum analysis
 - 2.8. Pushover analysis
 - 2.9. Time history analysis

- 3. Lateral Load Resisting Systems for Buildings (16 hours)**
 - 3.1. Different structural systems for lateral loads
 - 3.2. Floor diaphragms
 - 3.3. Lateral load distribution with rigid floor diaphragms
 - 3.4. Moment resisting frames
 - 3.5. Lateral load distribution in frame buildings
 - 3.6. Shear walls
 - 3.7. Shear wall with openings
 - 3.8. Frame – shear wall system

- 4. Hydro Dynamic Effects of Earthquake (6 hours)**
 - 4.1. Pressure against dam

- 4.2. Vibration of liquids in tanks
- 4.3. Vibrations of submerged structures like piers and caissons

5. Design of Structures for Earthquakes

(10 hours)

- 5.1. Plastic design of structures for earthquakes
- 5.2. Simplified design based on energy criterion
- 5.3. Ductility factor method
- 5.4. Code provisions

6. Introduction to Structural Control

(4 hours)

- 6.1. Active and passive control
- 6.2. Various technique of passive control
- 6.3. Overview of base isolation concept

Evaluation Schemes:

a. Internal Examination

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Examination

There will be 6 units of questions carrying marks as provided in the following table. The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Units	Chapter	Marks
1	1	2
2	2	20
3	3	15
4	4	8
5	5	12
6	6	3
Total		60

References:

1. Newmark, N. M., and Rosenblueth, E., **Fundamentals of Earthquake Engineering**, Prentice-Hall, Inc. Englewood Cliffs, N. J., 1971.
2. KRAMER, S.L, **Geotechnical Earthquake Engineering**, Prentice Hall, Upper Saddle River, NJ, 1996.
3. Dowrick, D., **Earthquake Resistant Design and Risk Reduction**, 2009, John Wiley & Sons, Ltd.
4. Chen, W.F. (Editor), Lui, E.M. (Editor), **Earthquake Engineering for Structural Design**, CRC (November 2, 2005)
5. Bolt, B., **Earthquakes**, Fifth Edition W. H. Freeman; 5th edition, October 17, 2003

6. Chopra, A.K., **Dynamics of Structures: Theory and Applications to Earthquake Engineering**, Prentice-Hall, Upper Saddle River, New Jersey, 2007.
7. Clough, R.W. and Penzien, J., **Dynamics of Structures**. McGraw-Hill, NY, 1993.
8. Elnashai, A., Sarno, L.D, **Fundamentals of Earthquake Engineering**. Copyright © 2008 by John Wiley & Sons, Ltd. ISBN: 978-0-470-02483-6, Hardcover 366 pages October 2008
9. Wakabayashi, M. , **Design of Earthquake Resistant Buildings**. McGraw-Hill, New York, 1986.
10. Datta, T. K., **Seismic Analysis of Structures**. John Wiley & Sons, Ltd., 2010.

Structural Health Monitoring
ENCEEQ 571

Lecture: 3 hrs.

Year: II

Tutorial: 1 hr.

Part: I

Practical: 0 hr.

Course Objectives:

This course aims to provide a comprehensive understanding of Structural Health Monitoring (SHM) by exploring various sensor technologies and their applications in civil engineering structures. Students will learn about data acquisition, transmission, processing, and management systems within SHM, along with utilizing SHM for identifying dynamic modal properties in structures. Additionally, the course will cover finite element model updating techniques.

Course Contents:

- 1. Introduction to Structural Health Monitoring (2 hours)**
 - 1.1. General introduction and historical background
 - 1.2. Structural assessment, structural monitoring and structural control
 - 1.3. SHM in civil engineering
 - 1.4. SHM system and its components
 - 1.5. SHM strategy and method
 - 1.6. Major advantages of SHM
 - 1.7. Challenges of SHM in civil engineering
- 2. Sensors and Sensing Technology for SHM (3 hours)**
 - 2.1. Sensor types
 - 2.2. Sensor measurements in structural monitoring
 - 2.3. Fibre optic sensors
 - 2.4. Magnetostrictive sensors
 - 2.5. Shape memory alloys
 - 2.6. Wireless sensors
 - 2.7. Optimum sensor selection
 - 2.8. Optimum sensor placement
 - 2.9. Case study
- 3. SHM Strategies and Methods (8 hours)**
 - 3.1. Short term and long-term monitoring
 - 3.2. Local and global monitoring
 - 3.3. Static and vibration-based health monitoring
 - 3.4. Planning SHM in civil infrastructures

- 4. Structural Damage Identification Techniques (3 hours)**
- 4.1. Non-destructive testing techniques
 - 4.2. Ultrasound
 - 4.3. Guided (Lamb) waves
 - 4.4. Thermography
 - 4.5. Electromagnetic methods
 - 4.6. Capacitive methods
- 5. Data Acquisition, Transmission and Management (10 hours)**
- 5.1. Data acquisition systems
 - 5.2. Data transmission systems
 - 5.3. Data processing systems
 - 5.4. Data management systems
 - 5.5. Case study
- 6. Damage Identification Methods (10 hours)**
- 6.1. Vibration-based monitoring and its components
 - 6.2. Damage identification with frequency and mode shapes
 - 6.3. Damage identification using lumped mass
 - 6.4. Damage identification using element modal stiffness
 - 6.5. Damage identification using modal strain energy
 - 6.6. Example problem for damage identification
 - 6.7. Comparison of vibration-based methods of damage detection
 - 6.8. Visual inspection methods for damage identification
- 7. Modal Analysis of Civil Engineering Structures (14 hours)**
- 7.1. Basic equations of structural dynamics
 - 7.2. Input-output modal identification
 - 7.3. Output-only modal identification
 - 7.4. Example problem for modal identification
 - 7.5. Correlation between test and calculated results
- 8. Finite Element Model Updating (10 hours)**
- 8.1. Finite element modeling
 - 8.2. Structural parameters for model updating
 - 8.3. Sensitivity based methods
 - 8.4. Example for model updating
 - 8.5. Dynamic perturbation method
 - 8.6. Dynamic perturbation method for model updating
 - 8.7. Case study

Evaluation Schemes:

a. Internal Examination

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Examination

There will be 8 units of questions carrying marks as provided in the following table. The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Units	Chapters	Marks
1	1	3
2	2	7
3	3	6
4	4	6
5	5	8
6	6	8
7	7	10
8	8	12
Total		60

References:

1. Karbhari, V. M. and Ansari, F., **Structural health monitoring of civil infrastructure systems**, Woodhead Publishing Limited, 2009.
2. Gandhi, M.V. and Thompson, B.D., **Smart materials and structures**, Springer Netherlands, 1992.
3. Chang, P.C., Flatau, A. and Liu, S.C., **Health monitoring of civil infrastructure**. *Structural Health Monitoring*, 2003, 2(3), 257–67.
4. Chen, H-P, **Structural health monitoring of large civil engineering structures**, Wiley Blackwell, 2018.
5. Shrestha et al., **Feasibility of Cu-Al-Mn superelastic alloy bar as a self-sensor material**, *Journal of Intelligent Material Systems and Structures*, 2015, Vol. 26, No. 3, pp. 364-370.
6. Araki et al., **Feasibility of tension braces using Cu-Al-Mn superelastic alloy bars**, *Structural Control and Health Monitoring*, 2014, Vol. 21, No. 10, pp. 1304-1315.
7. Brownjohn et al., **Vibration based monitoring of civil infrastructure: challenges and successes**. *Journal of Civil Structural Health Monitoring*, 2011, 2(1), 79–95.
8. Wong, K.Y. and Ni, Y.Q., **Modular architecture of structural health monitoring system for cable-supported bridges**, *Encyclopaedia of Structural Health Monitoring*, Boller, Chang and Fujino (ed.), John Wiley & Sons, Chichester, UK, 2009.

Seismic Resistant Design of Substructures
ENCEEQ 572

Lecture: 3 hrs.

Year: II

Tutorial: 1 hr.

Part: I

Practical: 0 hr.

Course Objectives:

In this course, students will be able to gain a deep understanding of how substructures respond to seismic loads. Advanced design methods for complex soil conditions and interactions are considered. Through hands-on exploration and testing, they'll acquire reliable soil parameters. They'll also study various ground improvement techniques to enhance substructure seismic performance and grasp soil-structure interaction principles.

Course Contents:

- 1. Introduction to Earthquake Resistant Design of Substructures (8 hours)**
 - 1.1. Overview of substructure design
 - 1.2. Importance of substructure's design codes
 - 1.3. Substructures in soft soil conditions
 - 1.4. Performance-based design for substructures
 - 1.5. Designing substructures in high-seismicity regions
- 2. Ground Exploration and Testing (8 hours)**
 - 2.1. Techniques for site investigation and characterization of soil properties
 - 2.2. Laboratory and in-situ testing methods for dynamic soil parameters determination
 - 2.3. Geophysical methods for assessing soil conditions and site response
 - 2.4. Ground motion monitoring and instrumentation techniques for accurate soil characterization
- 3. Ground Improvement Techniques (10 hours)**
 - 3.1. Dynamic compaction methods for enhancing subsoil density and strength
 - 3.2. Consolidation techniques for improving the load-bearing capacity of saturated soils
 - 3.3. Grouting methods for filling voids, improving soil strength, and reducing permeability
 - 3.4. Reinforcement approaches, such as geosynthetics, nails, piles for enhancing substructure stability and performance
- 4. Soil-Structure Interaction (8 hours)**
 - 4.1. Consideration of SSI in designing substructures
 - 4.2. Considerations of SSI in substructure's design codes
 - 4.3. Experimental testing and numerical simulation techniques for studying SSI and SSSI
- 5. Analysis and Design of Substructures (20 hours)**
 - 5.1. Analysis and design of shallow foundation: spread footings, and mat foundations
 - 5.2. Analysis and design of deep foundations: piles, shafts, and caissons

- 5.3. Analysis and design of flexible and rigid support systems
- 5.4. Analysis and design of basements and underground stories
- 5.5. Analysis and design of underground structures
- 5.6. Analysis and design of retaining structures

6. Case Studies and Complex Problems

(6 hours)

- 6.1. Advanced design for substructures
- 6.2. Design and implementation of seismic wave attenuation structures
- 6.3. Smart materials for enhancing seismic performance
- 6.4. Rapid and efficient substructure development

Evaluation Schemes:

a. Internal Examination

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Examination

There will be 6 units of questions carrying marks as provided in the following table. The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Units	Chapters	Marks
1	1	6
2	2	8
3	3	8
4	4	10
5	5	20
6	6	8
Total		60

References:

1. Agarwal, P. and Shrikhande, M., **Earthquake-Resistant Design of Structures**, PHI learning Private Limited, 2011.
2. Bowles J.E., **Foundation Analysis and Design**, McGraw-Hill, New York, 4th edition, 1988.
3. Das, B. M., Peck, R. B., and Mesri, G., **Principles of Foundation Engineering**, Cengage Learning, 8th edition, 2015.
4. Terzaghi K., **Soil Mechanics in Engineering Practice**, , 3rd edition, John Wiley and Sons, 3rd edition, 1996.
5. Kramer, S. L., **Geotechnical Earthquake Engineering**, Prentice-Hall Inc., 1996.