

Institute of Engineering, Thapathali Campus, Kathmandu

Course Structure 2024

MSc in Earthquake Engineering

Year : I

Part I

Teaching Schedule				Examination Scheme			Total	Remarks
SN	Course Code	Course Title	Credit	Assessment Marks	Final Exam			
					Duration Hours	Marks		
1	ENCEEQ501	Solid Mechanics	4	40	3	60	100	
2	ENCEEQ502	Theory of Vibrations	4	40	3	60	100	
3	ENCEEQ503	Engineering Seismology	4	40	3	60	100	
4	ENCEEQ504	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 Exam			
					Duration Hours	Marks		
1	ENCEEQ551	Seismic Resistant Design of Structures	4	40	3	60	100	
2	ENCEEQ552	Finite Element Methods	4	40	3	60	100	
3	ENCEEQ56X	Elective-I	4	40	3	60	100	
4	ENCEEQ57X	Elective-II	4	40	3	60	100	

		Total	16	160		240	400	
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Year : II

Part I

Teaching Schedule				Examination Scheme			Total	Remarks
S. N.	Course Code	Course Title	Credit	Assessment Marks	Final Exam			
					Duration Hours	Marks		
1	ENCEEQ61X	Elective-III	4	40	3	60	100	
2	ENCEEQ62X	Elective-IV	4	40	3	60	100	
3	ENCEEQ601	Project	4	100			100	
		Total	12	180		120	300	

Year: II

Part II

Teaching Schedule				Examination Scheme			Total	Remarks
S. N.	Course Code	Course Title	Credit	Assessment Marks	Final Exam			
					Duration Hours	Marks		
1	ENCEEQ651	Thesis	16	100			100	

Note: Students will write a thesis in the fourth semester. However, the thesis work must start from the beginning of third semester, which may be associated to the project work. Students can carry out the research thesis with one or more supervisors.

Elective Courses:

Elective courses will be offered as per the availability of resource persons. The lists of electives are as follows:

Elective I:

1. Computer Application for Earthquake Engineering [Code: ENCEEQ561]
2. Non-Linear Analysis of Structures [Code: ENCEEQ562]
3. Research Methodology [Code: ENCEEQ563]

Elective II:

1. Structural Health Monitoring [Code: ENCEEQ571]
2. Seismic Resistant Design of Substructures [Code: ENCEEQ572]
3. Design and Testing of Seismic Resistant Masonry [Code: ENCEEQ573]
4. Disaster Risk Evaluation, Policies and Management [Code: ENCEEQ574]

Elective III:

1. Advanced Optimization Techniques in Earthquake Engineering [Code: ENCEEQ611]
2. Performance Based Design of Structures [Code: ENCEEQ612]
3. Design of Industrial Structures [Code: ENCEEQ613]
4. Seismic Risk Assessment and Retrofitting Techniques [Code: ENCEEQ614]

Elective IV:

1. Application of AI Tools in Earthquake Engineering [Code: ENCEEQ621]
2. Structural Control and Base Isolation [Code: ENCEEQ622]
3. Design of Bridges [Code: ENCEEQ623]
4. Earthquake Engineering Laboratory [Code: ENCEEQ624]

Further Explanation about Project and Thesis works

The project and thesis component theme could be one of the following:

- Industrial/organizational problem assessment (mainly done at industry/organization)
- Community based problem assessment (mainly done at community)
- Literature based problem assessment (mainly done at institution)
- Analytical or experimental or prototype based problem assessment (mainly done at institution)
- Case study based problem assessment (mainly done at case specific site)
- Field work based problem assessment (mainly done at specific site)
- Any other relevant and deemed suitable by department
- The project component will be of approximately 3 months (full - time) duration

Eligibility and Degree Award:

Eligibility: **BE in Civil Engineering**

Degree Award: **MSc in Earthquake Engineering (Civil Engineering)**

Core Subjects

SOLID MECHANICS

ENCEEQ 501

Credits: 4

Year: I

Part: I

Course Objectives

This course aims to provide a comprehensive understanding of the mechanics of deformable bodies, with a strong emphasis on continuum mechanics. By the end of the course, students will be equipped to formulate and analyze the states of stress and strain, as well as understand their interrelations. Additionally, the course will cover various failure theories, applicable to both pressure-dependent and pressure-independent materials, offering a solid framework for understanding material behavior under diverse loading conditions.

1 Introduction **[4 hours]**

- 1.1 Tensor and continuum mechanics
- 1.2 Indicical notation and summation convention
- 1.3 Properties of tensor: equality, addition, multiplications
- 1.4 Transformations of coordinates
- 1.5 Operations on tensor

2 Analysis of Stresses **[12 hours]**

- 2.1 Body and surface forces
- 2.2 Definition stress at a point
- 2.3 Stress tensor at a point
- 2.4 Stress Transformation
- 2.5 Force and moment equations
- 2.6 Principle stress and axes
- 2.7 Spherical and deviatoric stress
- 2.8 Principal deviatoric stresses and invariants
- 2.9 Octahedral stresses
- 2.10 Geometric representation of stresses
- 2.11 Plane stress

3 Analysis of Strains **[12 hours]**

- 3.1 Definitions
- 3.2 Lagragian and Eularian description

- 3.3 Equation of continuity (Conservation of mass)
- 3.4 Strain tensors
- 3.5 Small strain tensor
- 3.6 Extension of line element
- 3.7 Shear between two orthogonal line elements
- 3.8 Geometrical meaning of small strain tensor
- 3.9 Rotation strain tensor
- 3.10 Relation between strain vector and strain tensor
- 3.11 Strain transformation
- 3.12 Linear strain displacement relationship by simplified method
- 3.13 Principle strain and axes
- 3.14 Cubical dilatation
- 3.15 Deviatoric strain tensor

4 Constitutive Relationship [12 hours]

- 4.1 Elastic solid
- 4.2 Constitutive equations
- 4.3 Strain energy functions
- 4.4 Anisotropic, isotropic and orthotropic solids
- 4.5 Elastic constants for orthotropic materials
- 4.6 Simple tension test
- 4.7 Formulation of problem of elasticity; displacement and stress formulations

5 Torsion [4 hours]

- 5.1 Torsional forces
- 5.2 Displacement formulation
- 5.3 Stress formulation

6 Plasticity of Solids [16 hours]

- 6.1 Elastic solid
- 6.2 Yield criterion
- 6.3 Pressure independent materials: Tresca and Von Mises yield criteria
- 6.4 Pressure dependent material: Mohr-Coulomb criteria, Drucker Prager criteria
- 6.5 Stress strain relation for perfectly plastic material: Criterion for loading and unloading
- 6.6 Elastic and plastic strain increment tensor
- 6.7 Flow rules
- 6.8 Incremental stress
- 6.9 General isotropic material

6.10 Stress strain relationship for elastoplastic deformation

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapters	Hours	Mark Distribution*
1 & 2	16	16
3	12	12
4	12	12
5 & 6	20	20
Total	60	60

*There may be minor deviation in marks distribution.

References

1. Hari R. Parajuli, (2015) Fundamentals of Solid Mechanics, Heritage Publishers and Distributors Pvt. Ltd., Bhotahity, Kathmandu, Nepal.
2. L. S. Srinath, Advanced Mechanics of Solid, Tata McGraw-Hill Publishing Company Limited, 1999
3. P. Karasudhi, Foundation of Solid Mechanics, Kluwer Academic Publishers, 1991
4. W. F. Chen and E. Mizuno, Nonlinear Analysis in Soil Mechanics: Theory and Implementation, Elsevier, 1990
5. W. F. Chen and H. Jhang, Structural Plasticity, Springer, 1991
6. W. F. Chen and D. J. Han, Plasticity for Engineers, Springer, 1988

THEORY OF VIBRATION

ENCEEQ 502

Credits: 4

Year: I

Part: I

Course Objectives

The objective of this course is to equip students with a comprehensive understanding of the vibrational behavior of structures and the fundamental principles necessary for structural and earthquake engineers to effectively address and resolve vibration-related challenges.

1 Introduction [2 hours]

- 1.1 Sources of vibration
- 1.2 Problems related to structural vibration
- 1.3 Degrees of freedom
- 1.4 Types of vibrations

2 Single Degree of Freedom (SDOF) System [15 hours]

- 2.1 Modeling of Single Degree of Freedom (SDOF) structures
- 2.2 Equation of motion of discrete system
- 2.3 Equation of motion for support motion of SDOF
- 2.4 Free vibration of un-damped SDOF system
- 2.5 Free vibration response of damped SDOF system
- 2.6 Forced vibration response of SDOF system to harmonic forces
- 2.7 Forced vibration response of SDOF system to periodic forces
- 2.8 Forced vibration response of SDOF system to impulsive forces
- 2.9 Forced vibration response of SDOF system to general dynamic forces
- 2.10 Time domain analysis
- 2.11 Frequency domain analysis

3 Multi Degree of Freedom (MDOF) System [15 hours]

- 3.1 Modeling of MDOF system structures
- 3.2 Equation of motion of MDOF system
- 3.3 Concept of generalized coordinate
- 3.4 Lagrange's equations of motion
- 3.5 Vibration absorption and orthogonality properties
- 3.6 Free vibration response (undamped and damped) of MDOF system
- 3.7 Natural frequencies and mode shapes

- 3.8 Normal coordinates and Normal Mode Theory
- 3.9 Practical methods to determine natural frequencies and mode shapes.
- 3.10 Mode superposition method
- 3.11 Forced vibration response of MDOF system including for support motions

4 Continuous System of Structures [10 hours]

- 4.1 Partial differential equations of motion (for string, bar, beam)
- 4.2 Axial vibration of a bar
- 4.3 Transverse vibration of a beam
- 4.4 Approximate methods to determine natural frequencies and mode shapes in cases where orthogonality conditions are not satisfied

5 Introduction to Non-linear Dynamic Analysis [8 hours]

- 5.1 Elastic and inelastic behavior
- 5.2 Incremental equations of equilibrium
- 5.3 Step-by-step integration method

6 Introduction to Random Vibration [10 hours]

- 6.1 Random variables
- 6.2 Probability and probability density
- 6.3 Joint probability density
- 6.4 Joint probability and independence
- 6.5 Stationary and ergodic processes
- 6.6 Autocorrelation function
- 6.7 Power spectral density function
- 6.8 Models of random excitations
- 6.9 Random earthquake motion

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Mark Distribution*
1	2	3
2	15	13
3	15	13
4	10	11
5	8	11
6	10	9
Total	60	60

*There may be minor deviation in marks distribution.

References

1. Clough R. W., Penzien J, **Dynamics of Structures**, McGraw Hill.
2. Chopra Anil, **Dynamics of Structures**, Prentice Hall.
3. Thomson W. T., **Theory of Vibration with Applications**, Prentice Hall.
4. Paz, Mario, **Structural Dynamics Theory & Computation**, Von Nostrad Reinhold Company, Inc.
5. Timoshenko, S. P., Young, D. H., Weaver, W., **Vibration Problems in Engineering**, John Wiley & Sons.
6. Yang C. Y., **Random Vibration of Structures**, John Wiley & sons.

ENGINEERING SEISMOLOGY

ENCEEQ 503

Credits: 4

Year: I

Part: I

Course Objectives

This course aims to equip students with a thorough understanding of earthquake phenomena, including their occurrence, propagation through various earth materials, and recording methodologies. Students will gain expertise in processing and analyzing seismic data to derive critical information essential for structural analysis and engineering applications.

1 Introduction [4 hours]

- 1.1 Basic concepts of engineering seismology
- 1.2 Seismology and earthquake engineering
- 1.3 Major Himalayan earthquakes
- 1.4 Effects of earthquakes, probable mitigation measures

2 Earth and Earthquake [8 hours]

- 2.1 Earth's internal structure
- 2.2 Plate tectonics- Continental drift, Plate boundaries
- 2.3 Global seismicity, Seismicity of the Himalaya
- 2.4 Seismic faults, Mechanics of faulting, Faults in Himalayan region

3 Waves Propagation [10 hours]

- 3.1 Elastic wave propagation, Wave equations
- 3.2 Wave propagation in in long rod, long shear beam, dispersion in long flexural beam
- 3.3 Seismic waves- Body waves, Surface waves
- 3.4 Reflection, refraction, attenuation of seismic waves
- 3.5 Seismic wave propagation in different media
- 3.6 Wave propagation in varied topography, layered half-space, and basins

4 Earthquake Generation [10 hours]

- 4.1 Causes of earthquakes
- 4.2 Mechanics and classification of earthquakes
- 4.3 Epicenter, hypocenter, shadow zones

- 4.4 Travel-time curves
- 4.5 Focal mechanism, P-T axis
- 4.6 Seismicity of subduction zone, inter-plate, intra-plate earthquakes, slow earthquakes, aseismic slip
- 4.7 Rupture directivity

5 Earthquake Recording [16 hours]

- 5.1 Seismometers and seismographs
- 5.2 Seismic networks and arrays
- 5.3 Ground motion parameters
- 5.4 Magnitude, intensity and earthquake energy
- 5.5 Earthquake return period and design earthquake
- 5.6 Earth noise, ambient noise
- 5.7 Strong-ground motion, Local site effects on strong ground motions
- 5.8 Ground motion prediction equation (GMPE)
- 5.9 Classifications of GMPEs, GMPEs for Himalayan region
- 5.10 Regression analysis for GMPE
- 5.11 Reflection and refraction seismology
- 5.12 Early warning system, Earthquake prediction

6 Seismic Signal Processing [12 hours]

- 6.1 Seismograms, Signal and noise, Seismic phases
- 6.2 Seismic data processing- Time domain, Frequency domain, Fast Fourier Transform, Filtering techniques
- 6.3 Fourier spectra, power spectra, response spectra
- 6.4 Ground motion parameters, ground motion scaling methods, spectra matching
- 6.5 Interpretation and analysis of earthquake data
- 6.6 Ground motion simulation
- 6.7 Generation of synthetic seismogram

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Mark Distribution*
1	4	4
2	8	8
3	10	11
4	10	11
5	16	14
6	12	12
Total	60	60

*There may be minor deviation in marks distribution.

References

1. Aki, R., & Richards, P. (2002), Quantitative Seismology, University Science Books.
2. Bormann, P. (Ed.) (2012), New Manual of Seismological Observatory Practice (NMSOP-2), IASPEI, GFZ German Research Centre for Geosciences, Potsdam; <http://nmsop.gfz-potsdam.de>; DOI: 10.2312/GFZ.NMSOP-2 urn:nbn:de:kobv:b103-NMSOP-2.
3. Havskov, J., & Ottemöller, L. (2010), Routine Data Processing in Earthquake Seismology, Springer, 347pp.
4. Kramer S, L. (1996), Geotechnical Earthquake Engineering, Prentice-Hall.
5. Scholz, C. H. (2012), The Mechanics of Earthquakes and Faulting, Cambridge University Press.
6. Shearer, P. M. (2009), Introduction to Seismology, Cambridge University Press, New York, 396 pp.
7. Stein, S., & Wysession, M. (2002), An Introduction to Seismology, Earthquake, and Earth Structure. Blackwell Publishing, Oxford, 498 pp.
8. Towhata, I. (2008), Geotechnical Earthquake Engineering, Springer.
9. Roberto Villaverde (2009), Fundamental of Earthquake Engineering, CRC Press.
10. Yokoi, T. (2010), Introduction to digital data processing (ver.3.3.1), International Institute of Seismology and Earthquake Engineering (IISEE).

GEOTECHNICAL EARTHQUAKE ENGINEERING

ENCEEQ 504

Credits: 4

Year: I

Part: I

Course Objectives

This course aims to equip students with an in-depth understanding of geotechnical earthquake engineering principles and theories. It focuses on advanced techniques for seismic hazard assessment, mechanisms of soil liquefaction, and analysis of slope stability. The course also explores ground improvement methods and foundation design, with a strong emphasis on addressing seismic forces and site-specific conditions.

1 Introduction [2 hours]

- 1.1 Background and scope
- 1.2 Review of seismology and earthquakes
- 1.3 Strong ground motion
- 1.4 Wave propagation

2 Seismic Hazard Assessment [8 hours]

- 2.1 Seismic hazard analysis; Deterministic & probabilistic
- 2.2 Database and completeness
- 2.3 Magnitude frequency relationship
- 2.4 Probabilistic hazard assessment methodology
 - 2.4.1 Source modeling
 - 2.4.2 Size of earthquakes
 - 2.4.3 Distance and attenuation laws
- 2.5 Epistemic and aleatory uncertainties
- 2.6 Temporal uncertainties
- 2.7 Logic trees
- 2.8 Probabilistic spectra
- 2.9 Disaggregation

3 Soil dynamics and soil dynamic properties [7 hours]

- 3.1 Mohr circles interpretation
- 3.2 Stress-strain behavior of cyclically loaded soils

- 3.3 Strength of cyclically loaded soils
- 3.4 Factors affecting shear modulus of soil
- 3.5 Field and laboratory tests
 - 3.5.1 Geotechnical tests
 - 3.5.2 Geophysical tests

4 Seismic Ground Response Analysis [7 hours]

- 4.1 Introduction
- 4.2 One dimensional ground response analysis
 - 4.2.1 Linear approach
 - 4.2.2 Equivalent approach
 - 4.2.3 Nonlinear approach
- 4.3 Two-dimensional ground response analysis
- 4.4 Three-dimensional ground response analysis

5 Local Site Effects and Design Ground Motions [8 hours]

- 5.1 Effects of local site conditions on Ground motion
- 5.2 Design parameters
- 5.3 Development of design parameters
- 5.4 Development of ground motion time histories

6 Bearing capacity analysis for earthquakes [3 hours]

- 6.1 Introduction
- 6.2 Bearing capacity for liquefied soil
- 6.3 Granular soil with earthquake-induced pore water pressures
- 6.4 Bearing capacity for cohesive soil

7 Soil Structure Interaction [8 hours]

- 7.1 Structural response and response spectra construction
- 7.2 Design based on seismic soil-structure interaction
- 7.3 Kinematic and inertial interaction
- 7.4 Vibration of foundation in elastic half space
- 7.5 Lumped parameter models
- 7.6 Advanced methods of analysis
 - 7.6.1 Direct method
 - 7.6.2 Substructure methods

8 Seismic soil Liquefaction

[6 hours]

- 8.1 Definition of soil liquefaction
- 8.2 Features of liquefaction-induced damages
- 8.3 Mechanism of onset of liquefaction phenomena
- 8.4 Liquefaction analysis
- 8.5 Behavior of soils undergoing cyclic undrained loading
- 8.6 Post-liquefaction behavior of soils
- 8.7 Mitigation of liquefaction-induced damage

9 Slope Stability

[5 hours]

- 9.1 Seismic behavior of slopes, embankments, and dams
- 9.2 Failure mechanism of slopes, embankments, and dams
- 9.3 Stability analysis of slopes, embankments, and dams
 - 9.3.1 Limit equilibrium method
 - 9.3.2 Stress deformation method
- 9.4 Mitigation of slope hazards

10 Design of earth structures

[6 hours]

- 10.1 Seismic pressure on earth structures
- 10.2 Seismic displacements of earth structures
- 10.3 Seismic design considerations
- 10.4 Seismic design and performance of isolation systems
- 10.5 Performance-based seismic design
- 10.6 Seismic design of underground structures

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Mark Distribution*
1	2	3
2	8	9
3	7	9
4	7	9
5	8	9
6	3	3
7	8	6
8	6	4
9	5	4
10	6	4
Total	60	60

*There may be minor deviation in marks distribution.

References

11. Hari Ram Parajuli and Bikram Bhusal, Site Specific Probabilistic Seismic Hazard Assessment of Nepal, 2018.
12. Aki, K., & Richards, P. G. Quantitative Seismology. University Science Books, 2002.
13. Das, B. M. Principles of Geotechnical Engineering. PWS Engineering, 1985.
14. Ishihara, K. Soil Behaviour in Earthquake Geotechnics. Oxford University Press, 1996.
15. Kramer, S. L. Geotechnical Earthquake Engineering. Pearson Education, Inc., 2013
16. Towhata, I., Geotechnical Earthquake Engineering. Springer, 2008.
17. Wolf, J. P. Dynamic Soil-Structure, 1985

SEISMIC RESISTANT DESIGN OF STRUCTURES

ENCEEQ 551

Credits: 4

Year: I

Part: II

Course Objectives

This course aims to provide a comprehensive understanding of seismic design principles and structural behavior under ground motion. It focuses on rational analysis and design strategies for structures exposed to strong ground motions, ensuring their integrity and safety in seismic-prone regions.

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 Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Mark Distribution *
1	4	2
2	20	20
3	16	15

4	6	8
5	10	12
6	4	3
Total	60	60

*There may be minor deviation in marks distribution.

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

FINITE ELEMENT METHOD

ENCEEQ 552

Credits: 4

Year: I

Part: II

Course Objectives

This course aims to bridge fundamental concepts in solid mechanics with advanced numerical methods for solving complex engineering problems. Students will learn to discretize intricate geometries into simpler, regular shapes, convert physical problems into mathematical models, and apply constitutive relations to develop stiffness matrices. The course will emphasize the use of iterative procedures to solve these models, providing a comprehensive understanding of numerical solutions in the context of structural engineering.

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 Galerkins'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 Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapters	Hours	Mark Distribution*
1,2,3&4	15	7
5	6	7
6	6	9
7	8	10
8	8	10
9	8	10
10 & 11	11	7
Total	60	60

*There may be minor deviation in marks distribution.

References

1. H. R. Parajuli, Analysis of Indeterminate Structures; Finite Element Approach, Heritage Publisher & Distributor Pvt. Ltd., Bhotahity, Kathmandu, Nepal, 2024.
2. D. V. Huttan, Fundamentals of Finite Element Analysis, TATA McGRAW-HILL, 2004.
3. J.N. Reddy, An Introduction to the Finite Element Method, McGRAW-HILL, 2005.
4. S. S. Bhavikatti, Finite Element Analysis, New Age International Publishers, 2005.
5. S. Rajasekaran, Finite Element Analysis in Engineering Design, S. CHAND, 2008.
6. T. R. Chandrapatla and A. D. Belegundu, Introduction to Finite Elements in Engineering, PHI, 2000.
7. R.D. Cook, D. S. Malkus and M. E. Plesha, Concepts and Applications of Finite Element Analysis, John Wiley & Sons, 2000.
8. C. S. Krishnamurthy, Finite Element Analysis- Theory and Programming, TATA McGRAW-HILL, 2000.

Elective Courses

COMPUTER APPLICATION FOR EARTHQUAKE ENGINEERING

ENCEEQ 561

Credits: 4

Year: I

Part: II

Course Objectives

The main objective of this graduate course is to equip students with a comprehensive understanding of key programming languages and tools necessary for advanced computational analysis in earthquake engineering. By the end of the course, students will have developed proficiency in C++ and Python programming, gained practical skills in utilizing OpenSees for structural analysis, and acquired advanced capabilities in MATLAB for data manipulation, numerical methods, and visualization. This knowledge will enable them to effectively model, analyze, and interpret complex seismic data and simulations, thereby enhancing their ability to address real-world challenges in earthquake engineering.

1 Introduction to 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, Real Time 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

Practical

[15 hours]

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The question will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Mark Distribution*
1	4	8
2	8	12
3	6	8
4	7	5
5	10	15
6	10	12
Total	45	60

*There may be minor deviation in marks distribution.

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

NON-LINEAR ANALYSIS OF STRUCTURES

ENCEEQ 562

Credits: 4

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.

- 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, 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 Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapters	Hours	Mark distribution*
1&2	8	4
3	16	15
4	10	15
5	6	3
6	8	8
7	12	15
Total	60	60

*There may be minor deviation in marks distribution.

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

Credits: 4

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.

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 result

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 Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Marks Distribution*
1	2	2
2	8	8
3	8	6
4	8	12
5	12	8
6	14	16
7	8	8
Total	60	60

*There may be minor deviation in marks distribution.

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.

STRUCTURAL HEALTH MONITORING

ENCEEQ 571

Credits: 4

Year: I

Part: II

Course Objectives

This course aims to provide comprehensive understanding of structural health monitoring by examining various sensor technologies and their applications in civil engineering structures. Students will gain expertise in data acquisition, transmission, processing, and management systems, and will learn to apply these techniques to identify dynamic modal properties of structures. The course will also cover methods for finite element model updating, enhancing the students' ability to assess and improve structural performance.

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 Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Mark Distribution*
1	2	3
2	3	7
3	8	6
4	3	6
5	10	8
6	10	8
7	14	10
8	10	12
Total		60

*There may be minor deviation in marks distribution.

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

Credits: 4

Year: I

Part: II

Course Objectives

This course aims to offer a comprehensive exploration of substructure behavior under seismic loads. By the end of the course, students will gain advanced knowledge in designing for complex soil conditions and interactions. They will develop skills in obtaining reliable soil parameters through practical exploration and testing. Additionally, students will examine various ground improvement techniques to optimize substructure seismic performance and understand the principles of soil-structure interaction.

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 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 and soil nails, 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 Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Mark Distribution*
1	8	6
2	8	8
3	10	8
4	8	10
5	20	20

6	6	8
Total	60	60

*There may be minor deviation in marks distribution.

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.

DESIGN AND TESTING OF SEISMIC RESISTANT MASONRY

ENCEEQ 573

Credits: 4

Year: I

Part: II

Course Objectives

The main objective of this course 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.

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 Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Mark Distribution*
1	6	8
2	7	12
3	10	15
4	6	5
5	6	8
6	10	12
Total	45	60

*There may be minor deviation in marks distribution.

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.
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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.
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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.

DISASTER RISK EVALUATION, POLICIES AND MANAGEMENT

ENCEEQ 574

Credits: 4

Year: I

Part: II

Course Objectives

The main objective of this course is to provide a comprehensive exploration of disaster risk evaluation methodologies, policies, and management strategies. By the end of the course, students will gain a robust understanding of disaster risk through theoretical frameworks, practical tools, and real-world case studies. The course emphasizes an interdisciplinary approach, integrating perspectives from geography, sociology, economics, and public policy to equip students with the skills needed for effective disaster risk assessment and management.

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 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 Earthquake-induced secondary hazards (e.g. Tsunamis, landslides)
- 7.2 Technological innovation for early warning and monitoring
- 7.3 Climate change and its impact on seismic risk

Assignments

The following practical exercise will be performed both in the laboratory and field.

1. Case study of recent disasters and its management
2. Analysis of Disaster Risk Reduction/Management strategies in global, national, and local scale
3. Analysis of past disaster database from different source: Desinventar, EM-DAT, DRRportal Nepal (<http://drrportal.gov.np>).

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Mark Distribution*
1	8	10
2	8	10
3	10	8
4	8	8

5	10	8
6	12	10
7	4	6
Total	60	60

*There may be minor deviation in marks distribution.

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ADVANCED OPTIMIZATION TECHNIQUES IN EARTHQUAKE ENGINEERING

ENCEEQ 611

Credits: 4

Year: II

Part: I

Course Objectives

The main objective of this course is to provide an in-depth understanding of advanced optimization techniques specifically designed for engineering applications. By the end of the course, students will have gained expertise in employing state-of-the-art optimization methods such as the Firefly Algorithm, Particle Swarm Optimization, and Genetic Algorithms. The course emphasizes practical application through real-world engineering problems, particularly focusing on structural optimization within the context of earthquake engineering. Students will develop a strong understanding of how these optimization tools can be leveraged to address and solve complex challenges in the field.

1 Introduction to Optimization Problem

[4 hours]

- 1.1. Statement of optimization problem
 - 1.1.1. Design vector/variables: Discrete, Continuous, Mixed
 - 1.1.2. Design constraints
 - 1.1.3. Constraint surface
 - 1.1.4. Objective function
 - 1.1.5. Objective function surfaces
- 1.2. Classification of optimization problem
- 1.3. Some Computational Aspects of Optimization
 - 1.3.1. Choice of Method
 - 1.3.2. Comparison of Unconstrained Methods
 - 1.3.3. Comparison of Constrained Methods
 - 1.3.4. Availability of Computer Programs
 - 1.3.5. Scaling of Design Variables and Constraints
 - 1.3.6. Computer Programs for Modern Methods of Optimization
- 1.4. Research trends and future directions in structural optimization field

2 Classical Optimization Techniques

[5 hours]

- 2.1 Single variable optimization

- 2.2 Multi-variable optimization with no constraints
- 2.3 Multi-variable optimization with equality and inequality constraints
- 2.4 Convex programming problem
- 2.5 Gradient-based optimization problem
- 2.6 Linear programming problem:
 - 2.6.1 Simplex method,
 - 2.6.2 Interior-point method
- 2.7 Non-linear programming problems
 - 2.7.1 Newton method,
 - 2.7.2 Quasi-Newton method,
 - 2.7.3 Secant method
- 2.8 Optimization Problems:
 - 2.8.1 Unconstrained optimization problems
 - 2.8.2 Constrained optimization problems
 - 2.8.3 Geometric programming problems
 - 2.8.4 Dynamic programming problems
 - 2.8.5 Integer programming problems
 - 2.8.6 Stochastic programming problems
- 2.9 Constraints handling
 - 2.9.1 Equality and inequality constraints
 - 2.9.2 Penalty function and barrier function methods
 - 2.9.3 Multi-constrained optimization problems

3 Advanced Optimization Methods

[6 hours]

- 3.1 Nature inspired optimization algorithm
- 3.2 Swarm intelligence approaches
- 3.3 Deterministic or stochastic algorithms
- 3.4 Gradient-based optimization method
- 3.5 Non-gradient-based optimization method
 - 3.5.1 Heuristics and metaheuristics approaches: Firefly Algorithms (FA), Particle Swarm Optimization (PSO), Genetic Algorithms (GA)
 - 3.5.2 Neural Network based optimization: Artificial Neural Network (ANN), Deep Neural Network (DNN), Convolution Neural Network (CNN)
 - 3.5.3 Optimization of Fuzzy system
 - 3.5.4 Machine Learning approach: Supervised learning, Unsupervised learning, Reinforcement learning

4 Practical Aspects of Optimization [2 hours]

- 4.1 Reduction of size of an optimization problem
 - 4.1.1 Reduced basis technique
 - 4.1.2 Design variable linkage technique
- 4.2 Fast reanalysis techniques
- 4.3 Derivatives of Eigen values and Eigen vectors
- 4.4 Derivatives of transient response
- 4.5 Sensitivity of optimum solution to problem parameters
- 4.6 Multi-level optimization: Basic ideal and methods
- 4.7 Parallel processing
- 4.8 Multi-objective optimization

5 Firefly Algorithms in Optimization [10 hours]

- 5.1 Introduction
- 5.2 Idealized rules
- 5.3 Fundamental concepts of algorithm
- 5.4 Attractiveness and Light absorption parameters
- 5.5 Special cases of FA
- 5.6 Exploration and exploitation behavior of algorithm
- 5.7 Position update equation and pseudo code for FA
- 5.8 Representation of design variables
- 5.9 Representation of objective function and constraints
- 5.10 Variants of FA:
 - 5.10.1 Discrete FA,
 - 5.10.2 Adaptive FA,
 - 5.10.3 Modified FA
 - 5.10.4 Enhanced FA
 - 5.10.5 Chaotic FA,
 - 5.10.6 Hybrid FA
 - 5.10.7 Multi-objective FA
- 5.11 Applications of FA and its variants

6 Other Popular Metaheuristic-based Optimization Algorithms [3 hours]

- 6.1 Genetic Algorithms

- 6.1.1 Algorithm equation and parameters
- 6.1.2 Pseudo code and flow chart of the algorithm procedure
- 6.1.3 Representation of objective function and constraints
- 6.2 PSO Algorithms
 - 6.2.1 Computational implementation of PSO
 - 6.2.2 Conceptual improvements and variants of PSO

7 Structural Optimization

[15 hours]

- 7.1 Types of optimizing structure
 - 7.1.1 Discrete structures
 - 7.1.2 Continuum structures
- 7.2 Structural optimization techniques
 - 7.2.1 Size optimization
 - 7.2.2 Topology optimization
 - 7.2.3 Shape optimization
 - 7.2.4 Support optimization
 - 7.2.5 Material optimization
- 7.3 Structural optimization problems
 - 7.3.1 Minimization problems
 - 7.3.2 Maximization
- 7.4 Objective functions:
 - 7.4.1 Weight-minimization,
 - 7.4.2 Volume-minimization,
 - 7.4.3 Compliance-minimization
- 7.5 Design variables
 - 7.5.1 Discrete design variables
 - 7.5.2 Continuous variables
 - 7.5.3 Mixed variables
- 7.6 Constraints in structural optimization

- 7.6.1 Kinematic stability constraints
- 7.6.2 Member-stress constraints
- 7.6.3 Joint-displacement constraints
- 7.6.4 Buckling constraints
- 7.6.5 Support constraints
- 7.6.6 Frequency constraints
- 7.6.7 Functionality constraints
- 7.6.8 Cost constraints
- 7.7 Size, shape, and topology optimization
 - 7.7.1 Truss structures
 - 7.7.2 RCC/Steel frame structures

Practical

[15 hours]

1. Coding approach for optimization problems based on programming languages: C++/Python/MATLAB.
2. Optimization Software's: C++ programming/MATLAB libraries/Python libraries/ FEA Software
3. Project work to write program for solving simple structural optimization problem (Truss and beam).
4. Presentations and discussions on project outcomes

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapters	Hours	Mark Distribution*
1 & 2	9	10
3 & 4	8	10
5	10	15
6	3	5
7	15	20
Total	45	60

*There may be minor deviation in marks distribution.

References

1. Topping, B.H.V., Optimization and Artificial Intelligence in Civil and Structural Engineering, Volume-I, Kluwer Academic Publishers, 1992.
2. Topping, B.H.V., Optimization and Artificial Intelligence in Civil and Structural Engineering, Volume-II, Kluwer Academic Publishers, 1992.
3. Parpinelli, R. and Lopes, H.S., Theory And New Applications Of Swarm Intelligence, Intech, 2012.
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12. Arora, J.S., Introduction to Optimum Design, second edition, Elsevier Inc., 2004.

PERFORMANCE BASED DESIGN OF STRUCTURES

ENCEEQ 612

Credits: 4

Year: II

Part: I

Course Objectives

The main objective of this course is to provide an in-depth understanding of advanced computational and modeling techniques crucial for tackling the challenges associated with population growth, urbanization, and the evolution of innovative structural systems. Students will acquire proficiency in state-of-the-art nonlinear analysis methods and contemporary computer modeling software, enhancing their understanding of the complex dynamic behaviors of structures. This knowledge will be vital for designing and analyzing increasingly dense, intricate, and high-rise urban infrastructure, equipping future structural engineers and designers to effectively address the demands of rapidly evolving urban environments.

- 1 Introduction** **[2 hours]**
 - 1.1 Understanding the Seismic Hazard
 - 1.2 Introduction to Seismology
 - 1.3 Seismic Hazard Assessment

- 2 Introduction to Performance Based Design Approach** **[16hours]**
 - 2.1 Dynamics of Structures – A Review
 - 2.2 Basic Philosophies of Seismic Design of Structures
 - 2.3 Introduction to Code-based Seismic Design
 - 2.3.1 Classical Modal Analysis Procedure
 - 2.3.2 Equivalent Lateral Force Procedure
 - 2.3.3 Response Spectrum Analysis Procedure
 - 2.4 From Code-based Design to PBD: Basics and Methodology
 - 2.5 Structural Performance Levels and Acceptance Criteria

- 3 Nonlinear Modeling and Behavior of Building Structures** **[12hours]**
 - 3.1 Quick overview of linear elastic modeling using FEM-based software
 - 3.2 Fundamentals of Nonlinear Modeling

- 3.2.1 Distributed and Lumped Plasticity Approaches
- 3.2.2 Hysteretic Behaviors, strength loss, cyclic degradation
- 3.3 Nonlinear Modeling of various structural components

4 Nonlinear Dynamic Analysis of Buildings [18 hours]

- 4.1 Selection of seismic input (Response Spectra and Ground Motion Records) for dynamic analysis of buildings, scaling and matching of ground motion records
Nonlinear Time History Analysis Procedure (NLTHA)
- 4.2 Interpreting the dynamic response and seismic performance of buildings, understanding the analysis results from nonlinear time history analysis
- 4.3 Understanding the analysis results from nonlinear time history analysis
- 4.4 Maximum considered earthquake (MCE) level evaluation of structural performance

5 Additional Topics [12 hours]

- 5.1 Nonlinear Static Procedures (NSPs), Pushover Analysis Procedures
 - 5.1.1 Single-mode pushover analysis procedures
 - 5.1.2 Multi-mode pushover analysis procedures
- 5.2 Capacity spectrum method, displacement coefficient method, FEMA 440 NSPs.
- 5.3 Introduction to Modal Pushover Analysis (MPA) procedure and Uncoupled Response History Analysis (UMRHA) procedures
- 5.4 Ductility design of structures
- 5.5 Direct Displacement-based Seismic Design (DDBD) of structures

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Marks Distribution*
1	2	4
2	16	16
3	12	12
4	18	16
5	12	12
Total	60	60

*There may be minor deviation in marks distribution.

References

1. T. Pauley, and M. J. N. Priestley, (1992): Seismic Design of Reinforced Concrete and Masonry Buildings, John Wiley and Sons, New York.
2. A. K. Chopra, (1995): Dynamics of Structures-Theory and Applications to Earthquake Engineering, Prentice Hall, New Jersey.
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13. Bungale S. Taranath (2010): Reinforced Concrete Design of Tall Buildings, Taylor and Francis Group, LLC.

DESIGN OF INDUSTRIAL STRUCTURES

ENCEEQ 613

Credits: 4

Year: II

Part: I

Course Objectives

This course aims to equip students with the specialized knowledge and skills required for designing robust and efficient structures tailored for industrial applications. It addresses unique challenges such as heavy loads, specialized equipment, and safety regulations, focusing on fundamental principles of structural design, material selection, analysis techniques, and compliance with industry standards. Students will be prepared for careers in industries such as manufacturing, petrochemicals, logistics, and utilities.

1 Design of Chimney Structure **[7 hours]**

- 1.1. Introduction
- 1.2. Design factors
 - 1.2.1. Self-weight of chimney
 - 1.2.2. Wind Pressure
 - 1.2.3. Temperature Stresses
- 1.3. Stresses in RC shaft due to self-wight and wind load
- 1.4. Stresses in hoop reinforcements due to shear force
- 1.5. Stresses due to temperature gradient
 - 1.5.1. Effect of temperature only on stresses in chimney walls
 - 1.5.2. Combined effect of wind loads, self-weight and temperature on stresses in chimney walls
 - 1.5.3. Stresses in horizontal reinforcement due to temperature difference
- 1.6. Design guidelines for reinforced concrete chimney
- 1.7. Design examples

2 Design of Bunker and Silo Structures **[7 hours]**

- 2.1 Introduction
- 2.2 Design of bunkers
 - 2.2.1 Design of bunkers with rectangular or square bottom
 - 2.2.2 Design of bunkers with circular bottom
- 2.3 Design examples of bunkers
- 2.4 Design of silos

- 2.4.1 Janssen's theory
- 2.4.2 Airy's theory
- 2.5 Silos for the storage of cement
- 2.6 Design examples of silos

3 Design of Tower Structures [7 hours]

- 3.1 Introduction
- 3.2 Design principles
- 3.3 Computation of moments due to wind loads
 - 3.3.1 Case I: Two columns hinged at base
 - 3.3.2 Case II: Three columns hinged at base
 - 3.3.3 Case III: Two columns fixed at base
 - 3.3.4 Case IV: Columns braced at intervals with fixed base
 - 3.3.5 Case V: Columns braced at intervals with hinged base
- 3.4 Wind load analysis of a tower with circular group of columns
- 3.5 Design examples

4 Design of Elevated Water Tank [6 hours]

- 4.1 Introduction
- 4.2 Types of overhead water tanks
- 4.3 Design of rectangular overhead tanks
- 4.4 Design of circular overhead tanks
- 4.5 Dome
- 4.6 Elevated Water Tank with Flat Bottom Slab
- 4.7 Design Examples

5 Design of Grid or Coffered Floors [6 hours]

- 5.1 Introduction
- 5.2 Analysis of Grid Floors
 - 5.2.1 Analysis of Grid Floors by Approximate Method
 - 5.2.2 Analysis of Grid Floor by Plate Theory Method
- 5.3 Design Examples
 - 5.3.1 Design Example using Approximate Method
 - 5.3.2 Design Example using Rigorous Method (Plate Theory Method)

6 Design of Shell Structures [7 hours]

- 6.1 Introduction

- 6.2 Shell Terminology
- 6.3 Advantages and Disadvantages of Shell Roofs
 - 6.3.1 Advantages of Shell Roofs
 - 6.3.2 Disadvantages of Shell Roofs
- 6.4 General Specifications of Shells
- 6.5 Behavior of Shells
- 6.6 Analysis of Shells
 - 6.6.1 Membrane Theory
 - 6.6.2 Design Example of Membrane Theory
- 6.7 Lundgreen's Beam Theory for Long Shells
 - 6.7.1 Beam Analysis
 - 6.7.2 Arch Analysis
 - 6.7.3 Design Examples of Beam and Arch Theories

7 Design of Folded Plates

[6 hours]

- 7.1 Introduction
- 7.2 Analysis of Folded Plates
- 7.3 Whitney's Method
- 7.4 Simpson's Method
- 7.5 Iteration Method
- 7.6 Beam Method
- 7.7 Winter and Pei's Method
- 7.8 Equation of Three Shears
- 7.9 Stress Conditions in Hipped Plates
- 7.10 Design Examples

8 Design of Gantry Girder

[7 hours]

- 8.1 Introduction
- 8.2 Loads
 - 8.2.1 Vertical Loads
 - 8.2.2 Impact Loads
 - 8.2.3 Lateral Loads
 - 8.2.4 Longitudinal Loads
- 8.3 Position of Moving Load for Maximum Effects
 - 8.3.1 Position of Crane Hook for Maximum Vertical Load on Gantry Girder
 - 8.3.2 Position of Crane Wheels for Maximum Effects on Gantry Girder
- 8.4 Limitation on Deflection

- 8.5 Design Procedure
 - 8.5.1 Assumptions
 - 8.5.2 Design Steps
- 8.6 Design Examples

9 Design of Transmission Towers

[7 hours]

- 9.1 Introduction
- 9.2 Types of Towers
- 9.3 Tower Configuration
- 9.4 Loads
 - 9.4.1 Weight of Tower
 - 9.4.2 Weight of Conductors and Ground Wires
 - 9.4.3 Wind Pressure
 - 9.4.4 Longitudinal Loads
- 9.5 Analysis
- 9.6 Member Selection

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Mark Distribution*
1	7	7
2	7	7
3	7	7
4	6	6

Chapter	Hours	Mark Distribution*
5	6	7
6	7	7
7	6	6
8	7	6
9	7	7
Total	60	60

*There may be minor deviation in marks distribution.

References

1. N. Krishna Raju, Advanced Reinforced Concrete Design (IS:456-2000), CBS Publishers and Distributors, Daryaganj, New Delhi, India.
2. Suwal Rajan, Design of Industrial Structures, Benchmark Publication, Tinkune, Kathmandu, Nepal.
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SEISMIC RISK ASSESSMENT AND RETROFITTING TECHNIQUES

ENCEEQ 614

Credits: 4

Year: II

Part: I

Course Objectives

The main objective of this course is to equip students with a comprehensive understanding of seismic event analysis, focusing on the assessment of hazards and the exposure of physical, socio-economic, and cultural elements to these hazards. By the end of the course, students will be proficient in evaluating the vulnerability of lifelines and infrastructure, understanding associated risks, and devising appropriate retrofitting strategies to maintain functionality post-event. This holistic approach is essential for effective risk assessment and the formulation of strategies to mitigate the impact of earthquakes on communities and infrastructure.

1 Introduction [2 hours]

- 1.1 Brief history of Nepalese and global significant earthquakes, their damages, death and loss
- 1.2 Hazard, exposure, vulnerability, and risk
- 1.3 Uses of Hazard and Risk Analysis

2 Seismic Hazard Simulation [5 hours]

- 2.1 Development of database
- 2.2 Seismic Hazard Source Model development
- 2.3 Attenuation laws/relationships
- 2.4 Hazard Curve
- 2.5 Model uncertainties
- 2.6 Monte Carlo PSHA
- 2.7 Logic tree
- 2.8 Uniform Hazard Spectrum
- 2.9 Disaggregation
- 2.10 Hazard maps

3 Strong Ground Motion Simulation [5 hours]

- 3.1 Seismic source characterization

- 3.2 Characterization of earthquake rates and generation of rupture scenarios
- 3.3 Engineering characterization of ground motion
- 3.4 Ground-motion database
- 3.5 Multiple regression analysis

4 Exposure Mapping **[6 hours]**

- 4.1 Identification of physical, social, economic, and cultural indicators
- 4.2 Spatial distribution: count, population, replacement cost, etc.
- 4.3 Mapping schemes
- 4.4 Uncertainties in exposure modeling
- 4.5 Exposure modeling

5 Vulnerability Assessment **[6 hours]**

- 5.1 Introduction to physical, social, cultural, and economic dimension of vulnerability,
- 5.2 Empirical assessment approach
 - 5.2.1 Rapid Visual Screening (RVS) Assessment
 - 5.2.2 Vulnerability Index Approach: GNDT method, RISK-UE method, and Combined method
- 5.3 Use of Capacity curves
- 5.4 Use of Fragility/Vulnerability curves

6 Loss Estimation **[8 hours]**

- 6.1 Quantitative risk assessment (QRA)
- 6.2 Event-tree analysis (ETA)
- 6.3 Risk Matrix approach (RMA)
- 6.4 Seismic risk indices, process-related risk indices (PRI)
- 6.5 Indicator-based approach (IBA)
- 6.6 Integrating seismic hazard to seismic risk
- 6.7 Consequence analysis

7 Tools and Techniques **[8 hours]**

- 7.1 RADIUS (Risk Assessment Tools for DIagnosis of Urban Areas against Seismic Disasters)
- 7.2 CAPRA-EQ (Probability Risk Assessment) Platform
- 7.3 OpenQuake Engine

- 7.3.1 Scenario, PSHA, Risk, and Damage Calculators,
- 7.3.2 Ground motion field and GMPEs
- 7.3.3 Source model and logic tree
- 7.3.4 Exposure model, Vulnerability functions, and Hazard Curves
- 7.3.5 Loss and Damage maps
- 7.4 HAZUS Model and Analysis levels: Basic and advanced

8 Seismic Risk Assessment of Lifelines and Infrastructures [8 hours]

- 8.1 Damage functions, definition of damage state, component restoration curves
- 8.2 Residential buildings
- 8.3 Essential and high potential loss facilities (hospitals)
- 8.4 Transportation systems (highway, roads, bridges, tunnels)
- 8.5 Water supply system (pipelines)
- 8.6 Electric power supply system
- 8.7 Communications system

9 Retrofitting Techniques [12 hours]

- 9.1 Basic concept of retrofitting
- 9.2 Existing retrofitting practice in Nepal
- 9.3 Retrofitting techniques for various structural systems
 - 9.3.1 RCC frame structures
 - 9.3.2 Steel frame structures
 - 9.3.3 Masonry buildings: Stone masonry, Brick masonry, Concrete block masonry, Autoclaved aerated concrete (AAC) masonry, etc.
 - 9.3.4 Hybrid structures
- 9.4 Retrofitting materials
 - 9.4.1 Steel bar for rebar jacketing
 - 9.4.2 Carbon fiber reinforced polymer (CFRP) for FRP wrapping/jacketing
 - 9.4.3 Carbon fiber reinforced polymer (GFRP)
 - 9.4.4 Aramid fiber reinforced polymer (AFRP)
 - 9.4.5 Polypropylene (PP) band for low-cost retrofitting
- 9.5 Available codes and guidelines for retrofitting design: IS, FEMA, ATC, etc
- 9.6 Analysis and design of RCC framed building using suitable retrofitting techniques
 - 9.6.1 FRP jacketing
 - 9.6.2 Rebar jacketing
- 9.7 Seismic retrofitting of non-ductile RC beam-column joint with externally bonded CFRP sheets

9.8 Foundation retrofitting techniques

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapters	Hours	Mark distribution*
1&2	7	5
3	5	5
4	6	5
5	6	5
6	8	5
7	8	10
8	8	10
9	12	15
Total	60	60

*There may be minor deviation in marks distribution.

References

1. Baker et al. (2021). Seismic Hazard and Risk Analysis, Cambridge University Press, Cambridge, England.
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APPLICATION OF AI TOOLS IN EARTHQUAKE ENGINEERING

ENCEEQ 621

Credits: 4

Year: II

Part: I

Course Objectives

This course aims to provide a comprehensive understanding of the application of Artificial Intelligence (AI) techniques in earthquake engineering. By the end of this course, students will be equipped to apply AI tools to address challenges in seismic hazard assessment, structural analysis, design optimization, and risk mitigation through theoretical knowledge and hands-on skills.

1 Introduction to Artificial Intelligence (AI)

[4 hours]

- 1.1 What is AI?
 - 1.1.1 Turning test approach
 - 1.1.2 Cognitive modeling approach
 - 1.1.3 Laws of thought approach
 - 1.1.4 Rational agent approach
- 1.2 Foundation of AI
 - 1.2.1 Philosophy
 - 1.2.2 Mathematics
 - 1.2.3 Economics
 - 1.2.4 Neurosciences
 - 1.2.5 Psychology
 - 1.2.6 Computer engineering
 - 1.2.7 Control theory and cybernetics
 - 1.2.8 Linguistics
- 1.3 History of AI

2 Emerging AI Methods

[6 hours]

- 2.1 Pattern Recognition (PR)
- 2.2 PR methods: Supervised PR, Unsupervised PR/Clustering
- 2.3 PR models: Generative, Discriminative
- 2.4 Statistical PR
- 2.5 Application of PR
- 2.6 Machine Learning (ML)

- 2.6.1 Supervised learning
- 2.6.2 Unsupervised learning
- 2.6.3 Reinforcement Learning (RL)
- 2.7 Deep Learning (DL)
- 2.8 DL architects in earthquake engineering
 - 2.8.1 Convolution Neural Networks (CNNs)
 - 2.8.2 Recurrent Neural Networks (RNNs)

3 AI Methods in Earthquake Engineering [15 hours]

- 3.1 Fundamental concept
- 3.2 Mostly used AI techniques:
 - 3.2.1 ML in earthquake engineering
 - 3.2.2 Swarm intelligence and metaheuristic approaches
 - 3.2.3 Neural network approaches
 - 3.2.4 Fuzzy logic
- 3.3 AI in Seismology
 - 3.3.1 AI approaches in seismic analysis
 - 3.3.2 Data-driven seismic prediction systems
 - 3.3.3 DL seismic prediction systems
 - 3.3.4 DL-enhanced seismology in IoT platform
- 3.4 AI in real-time monitoring and early warning systems
 - 3.4.1 Seismic monitoring and forecast
 - 3.4.2 Sensor technologies for earthquake detection
 - 3.4.3 Data processing and analysis
 - 3.4.4 Implementation of early warning systems

4 Relevant AI Tools and Techniques in Optimum Design of Structures [15 hours]

- 4.1 Optimum design techniques
 - 4.1.1 Size optimization
 - 4.1.2 Topology optimization
 - 4.1.3 Shape optimization
 - 4.1.4 Support optimization
 - 4.1.5 Material optimization
- 4.2 Optimization problems: Minimization problem, maximization problem
- 4.3 Typical objective functions:

- 4.3.1 Weight-minimization
- 4.3.2 Volume-minimization
- 4.3.3 Compliance minimization
- 4.4 Integration several constraints in structural optimization problem
 - 4.4.1 Kinematic Stability constraints: Truss mechanism, Grubler's condition, and Cholesky Decomposition, Positive definiteness of stiffness matrix
 - 4.4.2 Member-stress constraints
 - 4.4.3 Joint-displacement constraints
 - 4.4.4 Buckling constraints: Local and Global
 - 4.4.5 Support constraints
 - 4.4.6 Frequency constraints
 - 4.4.7 Functionality constraints
 - 4.4.8 Cost Constraints
- 4.5 Size and topology optimization for seismic performance of structures
- 4.6 Material allocation and layout optimization of structures
- 4.7 Application of AI tools in structural optimization and retrofitting
- 4.8 Case studies and applications in realistic structural problems

5 Future Applications of Emerging AI Tools

[5 hours]

- 5.1 Structural health monitoring
- 5.2 Seismic damage detection
- 5.3 Structural modification assessment
- 5.4 Seismic performance evaluation
- 5.5 Earthquake risk evaluation
- 5.6 Risk-based management
- 5.7 Material properties prediction
- 5.8 Crack categorization
- 5.9 Earthquake prediction Model

Assignments

[15 hours]

1. Analysis and comparing the research outputs from minimum five research papers published in reputed international journals.
2. Write a concise review paper on structural optimization.
3. Solve a realistic truss optimization problem using available software tools, preferred MATLAB/FEM-based software
4. Write a program to solve small sized steel truss optimization problem considering several constraints, using Firefly Algorithms.

- Solve a truss optimization problem considering multiple loading.

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Mark Distribution*
1	4	5
2	6	10
3	15	20
4	15	20
5	5	5
Total	45	60

*There may be minor deviation in marks distribution.

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12. Timothy J. Ross, Fuzzy Logic With Engineering Applications, Third Edition, John Wiley & Sons, 2010.
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STRUCTURAL CONTROL AND BASE ISOLATION

ENCEEQ 622

Credits: 4

Year: II

Part: I

Course Objectives

The main objective of this course is to equip students with a comprehensive understanding of the concepts and theories behind energy dissipative devices and their application in controlling the seismic response of structures, including base isolation. Additionally, the course aims to provide students with the knowledge and skills needed to simulate and evaluate the seismic response of structures using these control devices.

1 Basic Concepts of Structural Control [4 hours]

- 1.1 Historical development
- 1.2 Conventional forced-based seismic design
- 1.3 Performance based seismic design
- 1.4 Type of structural control systems
- 1.5 Energy concept in earthquake engineering

2 Passive Energy Dissipation Devices [10 hours]

- 2.1 Fundamental concepts of passive energy dissipation systems
- 2.2 Metallic dampers
- 2.3 Friction dampers
- 2.4 Fluid viscous dampers
- 2.5 Tuned mass dampers
- 2.6 Tuned liquid dampers
- 2.7 Linear Viscoelastic behavior
 - 2.7.1 Storage and loss stiffness, loss tangent
 - 2.7.2 Concept of equivalent linear analysis
 - 2.7.3 Modal damping ratios and effective damping coefficients
 - 2.7.4 Frequency domain response
- 2.8 Viscoelastic dampers
- 2.9 Introduction of self-centering systems

- 3 Application of Passive Energy Dissipation Devices in the Structures [8 hours]**
- 3.1 SDOF systems with different dampers, structural applications
 - 3.2 MDOF system with different dampers, structural applications
 - 3.3 Solution techniques:
 - 3.3.1 Iterative methods
 - 3.3.2 Runge-Kutta method
 - 3.3.3 Modal Strain Energy Method
 - 3.3.4 State-space solution
 - 3.3.5 Response spectrum method of analysis
- 4 Introduction to Active, Semi-active and Hybrid Energy Dissipation Systems [4 hours]**
- 4.1 Stability, Controllability and Observability
 - 4.2 State Observer
 - 4.3 Active tuned mass dampers; active tendon system
 - 4.4 Active Control Algorithms: Pole placement technique, classical linear optimal control, instantaneous optimal control, practical limitations
 - 4.5 Introduction to semi-active energy dissipation systems: Stiffness bracing system; ER/MR dampers; TMDs and TLCs
 - 4.5.1 Emerging technologies in semi-active control
 - 4.5.2 Semi-active control algorithms
 - 4.6 Introduction to hybrid energy dissipation systems: Actuator/ATMD
- 5 Introduction to Base Isolation [3 hours]**
- 5.1 History of base isolation technology and its application
 - 5.2 Concept of base isolation
 - 5.3 Principle of base isolation
 - 5.4 Suitability of base isolation
- 6 Introduction to Base Isolation Systems and Properties [3 hours]**
- 6.1 Laminated rubber bearing (LRB)
 - 6.2 New Zealand bearing system
 - 6.3 High damping rubber bearing (HDRB)
 - 6.4 Pure friction systems; Friction pendulum systems (FPS)
- 7 Mechanical Characteristics, Modeling and Design of Isolators [4 hours]**
- 7.1 Elastomeric bearing
 - 7.2 LRB, HDRB

7.3 FPS

8 Analysis and Design of Base Isolated Buildings [9 hours]

- 8.1 Analysis of base isolated buildings with isolated footings
- 8.2 Analysis of base isolated building with base slab
- 8.3 Solution methods of base isolated building:
 - 8.3.1 Equivalent static force procedure
 - 8.3.2 Response spectrum procedure
 - 8.3.3 Nonlinear time-history analysis
- 8.4 Code base requirements
- 8.5 Anchorage and base plate design
- 8.6 Detailing and construction
- 8.7 Design of Base Isolated Buildings
 - 8.7.1 Design stages
 - 8.7.2 Preliminary design: Design of Isolator and initial sizing of the isolated structure
- 8.8 Response spectrum analysis of base isolated structure
- 8.9 Non-linear time history analysis
- 8.10 Observed responses of base-isolated structures

Assignments and Projects [15 hours]

Assignments

1. Modelling and design of passive energy dissipative systems
2. Application of passive dissipative systems in structures
3. Problems on active, semi-active and hybrid control systems
4. Problems on the modeling and design of LRB, HDRB, FPS bearings
5. Design of the base isolated structures using LRB, HDRB, FPS and other energy dissipative systems

Projects

1. Write the program to solve SDOF systems with metallic dampers and solve it to find the response.
2. Write the program to solve SDOF systems with viscous dampers and solve it to find the response.
3. Write the program to solve MDOF systems with metallic dampers and solve it to find the response.

4. Write the program to solve MDOF systems with viscous dampers and solve it to find the response.

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapters	Hours	Mark Distribution*
1	4	4
2	10	14
3	8	11
4	4	5
5& 6	6	8
7	4	5
8	9	12
Total	45	60

References

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3. F. Naeim and J. M. Kelly, Design of Seismic Isolated Structures: From Theory to Practice, John Wiley & Sons, Inc. 1999.
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5. T. E. Kelly, Base Isolation of Structures Design Guidelines, Holmes Consulting Group Ltd, July 2001.
6. T. K. Datta, Seismic Analysis of Structures, John Wiley & Sons Ltd., 2010.
7. A. K. Chopra, Dynamics of Structures, Prentice Hall.

DESIGN OF BRIDGES

ENCEEQ 623

Credits: 4

Year: II

Part: I

Course Objectives

This course aims to provide students with essential skills in designing bridges, encompassing aesthetics, geographical considerations, and functionality. It covers fundamental concepts in bridge hydrology and geotechnical studies, load analysis, and the design process from conceptualization to element sizing. Furthermore, the course covers the specification of appropriate components for bridge bearings and expansion joints, methods of bridge construction, and processes for bridge evaluation, maintenance and rehabilitation.

1 Introduction to Bridge Structures [4 hours]

- 1.1. Historical review and current issues
- 1.2. Types of bridges and its characters
- 1.3. Selection of appropriate types and location of bridges
- 1.4. Aesthetic in bridge design

2 Fundamentals for Design and Analysis of Bridges [6 hours]

- 2.1 Norms and standards
- 2.2 General design requirements
- 2.3 Bridge hydrology
- 2.4 Bridge site investigation and geotechnical study

3 Analysis and Design of Bridge Superstructures [20 hours]

- 3.1 Bridge loading
- 3.2 Limit state design for road bridges
- 3.3 Analysis and design of reinforced concrete slab bridges
- 3.4 Theory of lateral load distribution
- 3.5 Grillage idealization of slab and T-girder bridges
- 3.6 Analysis and design of RCC T-beam and slab bridges

- 3.7 Analysis and design of steel plate girder and truss bridges
- 3.8 Analysis and design of prestressed concrete girder bridges
- 3.9 Introduction to long span bridges
- 3.10 FE modeling and dynamic analysis of bridge

4 Analysis and Design of Bridge Substructure and Foundation [15 hours]

- 4.1 Bridge abutments: Design considerations, types of abutments, Forces acting on abutments, stability analysis
- 4.2 Bridge piers: Design considerations, types of piers, fixing the size of piers, forces acting on piers, stability analysis
- 4.3 Design consideration of shallow and deep foundation
- 4.4 Pushover analysis of bridge piers

5 Bridge Bearing and Expansion Joints [5 hours]

- 5.1 Types and suitability of different types
- 5.2 Construction and maintenance consideration

6 Methods of Bridge Construction [5 hours]

- 6.1 Description of suitability of different construction methods
- 6.2 Emergency construction of strategic bridges

7 Existing Bridges Evaluation, Maintenance and Rehabilitation [5 hours]

- 7.1 Type of maintenance
- 7.2 Condition rating of bridge
- 7.3 Rehabilitation and replacement methods

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	70%
Assignments	30%

b. Final Exam

The question will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

Chapter	Hours	Mark Distribution*
1	4	4
2	6	6
3	20	20
4	15	15
5	5	5
6	5	5
7	5	5
Total	60	60

*There may be minor deviation in marks distribution.

References

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3. S. Swami (2019), Analysis and Design of substructures, Oxford and IBH publishing Co. Pvt. Ltd. New Delhi
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EARTHQUAKE ENGINEERING LABORATORY

ENCEEQ 624

Credits: 4

Year: II

Part: I

Course Objectives

The primary aim of this course is to offer a comprehensive understanding of seismic loading principles and their effects on structures. By the end of the course, students will be proficient in designing and conducting controlled seismic experiments without compromising structural integrity. They will gain skills in analyzing and detecting potential damage conditions using experimental data, which will enhance their comprehension of structural behavior during earthquakes. This expertise will enable them to improve design and construction practices for increased resilience, develop effective earthquake risk mitigation strategies, and advocate for safer construction standards. Students will be equipped to contribute to more resilient built environments through informed design and innovative solutions for reducing earthquake damage.

1 Non-Destructive Testing [3 hours]

- 1.1. Schmidt hammer test
- 1.2. Strain gauge
- 1.3. Piezoelectric sensing
- 1.4. Accelerometer and Gyroscope sensor
- 1.5. Seismometer and seismograph
- 1.6. Linear Variable Differential Transformer (LVDT) displacement sensor
- 1.7. Ultrasonic pulse velocity testing
- 1.8. Eddy current testing

2 Micro-Tremor Measurement [3 hours]

- 2.1 Introduction to micro tremors
- 2.2 Micro tremor propagation
- 2.3 Active and passive surface wave methods
- 2.4 1D Active MASW (Multi-channel Analysis of Surface Waves) survey

- 2.4.1 Length of survey line
- 2.4.2 Site classification VS30 survey
- 2.4.3 Geophone interval, stacking, shots
- 2.4.4 Active and passive source surface waves
- 2.4.5 Dispersion curve
- 2.4.6 S-wave velocity model
- 2.5 SeisImager/SW software

3 Pseudo-Dynamic Testing

[3 hours]

- 3.1 Introduction
- 3.2 Sub-structuring technique
- 3.3 Experimental and/or Numerical substructure modules
- 3.4 Integration modules
- 3.5 Communication methods
- 3.6 Data acquisition
- 3.7 Typical Instrumentation
 - 3.7.1 Servo-hydraulic actuators
 - 3.7.2 Displacement transducers
 - 3.7.3 Anchorages
 - 3.7.4 Reaction wall
 - 3.7.5 Supporting mechanism
- 3.8 Example application

4 Shock Table Test

[3 hours]

- 4.1 Introduction
- 4.2 Components of a shock table
 - 4.2.1 Shock table/platform
 - 4.2.2 Impact hammer
 - 4.2.3 Accelerometers
- 4.3 Operation mechanism
- 4.4 Example application

5 Shake Table Test

[3 hours]

- 5.1 Introduction to shake table

- 5.1.1 What is a shake table?
- 5.1.2 Types of shake table
- 5.1.3 Shake tables around the world
- 5.1.4 Applications
- 5.2 Components of a shake table
 - 5.2.1 Shake table/platform
 - 5.2.2 Actuator assemblies
 - 5.2.3 Power supply system
 - 5.2.4 Control panel
 - 5.2.5 Supporting mechanism
- 5.3 Operation mechanism
- 5.4 Building an inexpensive shake table

Practical

- 1. Non-destructive tests (NDTs) to evaluate strength of concrete **[5 hours]**
- 2. Micro-tremor measurement **[10 hours]**
- 3. Pseudo-dynamic test involving cyclic test (For example: Cyclic in-plane shear tests on masonry walls or concrete walls) **[10 hours]**
- 4. Shock table test / Shake table test on reduced scale specimen (For example: Reduced scale one story house) involving measurements of dynamic characteristics of the specimen during the test **[20 hours]**

Evaluation Schemes

a. Internal Evaluation

Type	Weightage
Minor tests	50%
Report writing	50%

b. Final Exam

There will be no final examination for this course.

References

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- 2. S. K. Dwivedi, M. Vishwakarma, and A. Soni, Advances and researches on non destructive testing: A review, Materials Today: Proceedings, 5(2), 3690-3698, 2018.

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