

Theory of Vibration
ENCEEQ 502

Lecture: 3 hr.
Tutorial: 1 hr.
Practical: 0 hr.

Year: I
Part: I

Course Objectives:

The course gives a basic understanding of the vibrational behavior of structures along with the underlying principles, which are necessary to tackle with the vibration problems by structural and earthquake engineers.

Course Contents:

- 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** (10 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** (10 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

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Practical Method*

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3.11. Forced vibration response of MDOF system including for support motions

4. Continuous System of Structures

(8 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

(7 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 Examination

| Type | Weightage |
|-------------|-----------|
| Minor tests | 70% |
| Assignments | 30% |

b. Final Examination

There will be 5 units of questions carrying marks as provided in the following table. The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

| Units | Chapters | Marks |
|-------|----------|-------|
| 1 | 1 | 3 |
| 2 | 2 | 13 |
| 3 | 3 | 13 |
| 4 | 4 | 11 |
| 5 | 5 | 11 |
| 6 | 6 | 9 |
| Total | | 60 |

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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.

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- 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 (8 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 (5 hours)

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

6. Plasticity of Solids (12 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 Examination

| Type | Weightage |
|-------------|-----------|
| Minor tests | 70% |
| Assignments | 30% |

b. Final Examination

There will be 5 units of questions carrying marks as provided in the following table. The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

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| Units | Chapters | Marks |
|-------|----------|-------|
| 1 | 1 & 2 | 16 |
| 2 | 3 | 12 |
| 3 | 4 | 8 |
| 4 | 5 & 6 | 6 |
| 5 | 7 & 8 | 18 |
| Total | | 60 |

References:

1. Hari R. Parajuli, **Fundamentals of Solid Mechanics**, Heritage Publishers, 2023
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

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Hari R. Parajuli

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Rev. Nath Maskey

Geotechnical Earthquake Engineering
ENCEEQ 504

Lecture: 3 hr.
Tutorial: 1 hr.
Practical: 0 hr.

Year: I
Part: I

Course Objectives:

This program aims to provide a comprehensive grasp of geotechnical earthquake engineering principles and theories. Participants will delve into advanced seismic hazard assessment techniques, soil liquefaction mechanisms, and slope stability analysis. Additionally, the curriculum covers ground improvement techniques and foundation design, emphasizing 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

(6 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

(6 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

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- 4. Seismic Ground Response Analysis** (6 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** [6 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** (2 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** (5 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** (4 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** (4 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

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- 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
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 - 9.3. Stability analysis of slopes, embankments, and dams
 - 9.3.1. Limit equilibrium method

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- 9.3.2. Stress deformation method
- 9.4. Mitigation of slope hazards

10. Design of earth structures

[4 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 Examination

| Type | Weightage |
|-------------|-----------|
| Minor tests | 70% |
| Assignments | 30% |

b. Final Examination

There will be 10 units of questions carrying marks as provided in the following table. The questions will cover all chapters of the syllabus. The evaluation scheme will be as indicated in the table:

| Units | Chapters | Marks |
|--------------|----------|-----------|
| 1 | 1 | 3 |
| 2 | 2 | 9 |
| 3 | 3 | 9 |
| 4 | 4 | 9 |
| 5 | 5 | 9 |
| 6 | 6 | 3 |
| 7 | 7 | 6 |
| 8 | 8 | 4 |
| 9 | 9 | 4 |
| 10 | 10 | 4 |
| Total | | 60 |

References:

1. Aki, K., & Richards, P. G. **Quantitative Seismology**. University Science Books, 2002.
2. Chopra, K. **Dynamics of Structures: Theory and Applications to Earthquake Engineering**. Pearson Prentice-Hall, 2009.
3. Das, B. M. **Principles of Geotechnical Engineering**. PWS Engineering, 1985.
4. Ishihara, K. **Soil Behaviour in Earthquake Geotechnics**. Oxford University Press, 1996.
5. Kramer, S. L. **Geotechnical Earthquake Engineering**. Pearson Education, Inc., 2013
6. Towhata, I. (2008). **Geotechnical Earthquake Engineering**. Springer, 2008.
7. Wolf, J. P. **Dynamic Soil-Structure**, 1985

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 Hari R. Panigrahi ¹²

Engineering Seismology
ENCEEQ 503

Lecture: 3 hrs.

Year: I

Tutorial: 1 hr.

Part: I

Practical: 0 hr.

Course Objectives:

This course will give knowledge about how earthquakes occur, how seismic waves propagate in different types of earth materials, how earthquakes are recorded and how one can process and analyze the recorded seismic data to extract information necessary for structural analysis.

Course Contents:

- 1. Introduction (3 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 (6 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 (8 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 (8 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

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5. Earthquake Recording

(12 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

(8 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 Examination

| Type | Weightage |
|-------------|-----------|
| Minor tests | 70% |
| Assignments | 30% |

b. Final Examination

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

| Chapter | Chapter | Marks |
|---------|---------|-------|
| 1 | 1 | 4 |
| 2 | 2 | 8 |
| 3 | 3 | 11 |
| 4 | 4 | 11 |
| 5 | 5 | 14 |
| 6 | 6 | 12 |
| Total | | 60 |

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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).

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