Course guide
295454 - 295TM121 - Structural Dynamics and Seismic Engineering

Last modified: 26/06/2024

Unit in charge: Barcelona East School of Engineering
Teaching unit: 737 - RMEE - Department of Strength of Materials and Structural Engineering.

Degree: MASTER'S DEGREE IN MECHANICAL TECHNOLOGIES (Syllabus 2024). (Optional subject).

Academic year: 2024 **ECTS Credits:** 6.0 **Languages:** Spanish

LECTURER

Coordinating lecturer: Ramón González Drigo

Others: Jorge Arturo Avila Haro
Rodrigo Esteban Alva Bañuelos

PRIOR SKILLS

Ability to design algorithms to solve fundamental problems of calculus and matrix algebra.
Ability to implement mathematical algorithms in the Python language and, additionally, using a Matlab platform.

TEACHING METHODOLOGY

The subject is based on master classes (aprox. 65%), and practical classes developed in a computer room (aprox 35%).
Master classes on theory and problem solving.
Practical classes in a computer room (Python, Matlab, others).

LEARNING OBJECTIVES OF THE SUBJECT

The overall aims of this course are:
1. Introduction to basic and specific concepts and vocabulary related to seismology and dynamics.
2. Acquire a basic vocabulary specific to the area of seismology and structure dynamics.
3. Ability to read and understand texts, figures and tables included in scientific-technical literature related to basic seismology and dynamic analysis of structures.
4. Ability for correct and effective oral or written expression on issues related to the field of structural dynamics.
5. Understand the dynamic response mechanisms of one degree of freedom systems with and without damping.
6. Approach and knowledge of the set of techniques and procedures used in the dynamic analysis of structures with n degrees of freedom with and without damping.
7. Development of capabilities to verify compliance with the Earthquake-resistant Standard in the case of structures with n degrees of freedom.
8. Acquire ability and competence to write and manage computer calculation codes.
9. Acquire knowledge of basic bibliography and the ability to perform bibliographic searches related to the dynamic calculation of structures.
10. Acquire knowledge about information sources related to public or private administrations and related to seismology and dynamic analysis of structures.
11. Ability to develop software related to the subject's syllabus.
12. Acquire skills for autonomous learning.

STUDY LOAD

Type	Hours	Percentage
Self study	108,0	72.00
Hours large group	21,0	14.00
Hours small group	21,0	14.00

Total learning time: 150 h

CONTENTS

Topic 1. Elements of seismology

Description:
Introduction. Internal structure of the Earth. Tectonic plates. Earthquakes and seismic zones. Mechanisms of tectonic earthquakes. Seismic waves. Recording of seismic waves. Seismic attenuation. Destructive potential of earthquakes. Seismic scales. Seismic hazard, vulnerability and risk.

Specific objectives:
Know the internal structure of the earth. Relate cortical dynamics to the generation of tectonic earthquakes. Know other natural causes of earthquakes. Know the types of waves transmitted during an earthquake. Know the structure and operation of a seismic network. Distinguish intensity scales and magnitude scales. Know the Richter scale. Know the European Macroseismic Scale. Know the relationships between intensity, distance and magnitude. Know the definitions of seismic hazard, seismic vulnerability and seismic risk. Correctly relate the previous definitions. Know the theoretical foundations of Fourier analysis. Know the Duhamel integral and be able to design a numerical algorithm for its calculation. Ability to perform modal analysis. In general, ability to develop calculation programs related to the subject syllabus. Know the earthquake-resistant construction regulations.

Full-or-part-time: 3h
Theory classes: 3h

Topic 2. Undamped one degree of freedom systems

Description:
Vibration systems. Degrees of freedom. Undamped systems. Stiffness Association (serie and parallel). Differential equation of motion. Solution and initial conditions. The system's natural frequency. Amplitude, frequency and period.

Full-or-part-time: 1h
Theory classes: 1h

Topic 3. Damped one degree of freedom systems

Description:
Damped systems with 1 degree of freedom. Energy dissipation mechanisms and viscous damping models. Differential equation of motion. Three damping conditions. Critical damping. Underdamped and overdamped systems. Experimental determination of damping using the logarithmic decrement technique.

Specific objectives:
Know the resolution of the differential equation of motion for three damping situations (critical, underdamped and overdamped). Be able to calculate the damping of a system using the logarithmic decrement technique.

Full-or-part-time: 2h
Theory classes: 2h

Topic 4. Response to harmonic loading

Description:
Response of one degree of freedom systems to harmonic excitations. Harmonic excitation of undamped one-degree-of-freedom systems. Harmonic excitation of damped one-degree-of-freedom systems. Determination of damping in the resonance condition. Determination of damping by the bandwidth method. Response to movement of the base or support. Shear transmitted to the foundation. Seismic instrumentation.

Specific objectives:
Ability to deduce and solve the differential equation of the response of systems with one degree of freedom subjected to harmonic excitations (for systems with one degree of freedom without damping and for systems with one degree of freedom with damping). Ability to determine the damping of a one degree of freedom system in the resonance condition. Ability to calculate damping using the bandwidth method. Calculate the response to the movement of the base or support based on the corresponding differential equation. Calculate the shear transmitted to the foundation. Know the basic operation of seismic instrumentation. Recognize the importance of the instrumental response in measuring seismic action.

Full-or-part-time: 2h
Theory classes: 2h

Topic 5. General dynamic excitations

Description:
Response to general dynamic excitations. The impulse and the Duhamel integral. Example of calculation with constant force. Example of calculation with rectangular force. Example of calculation with triangular force. Numerical calculation of the Duhamel integral with damped and undamped systems.

Specific objectives:
Identify possible general dynamic excitations. Know the deduction of the Duhamel integral from the differential impulse of a general excitation. Ability to calculate the response to three specific excitations using the Duhamel integral (Calculation with constant load, calculation with rectangular load and calculation with triangular load). Be able to develop the algorithm necessary to numerically calculate the Duhamel integral for systems without damping and for systems with damping.

Full-or-part-time: 3h
Theory classes: 3h

Topic 6. Fourier analysis

Description:
Fourier analysis and response in the frequency domain. Fourier analysis. Response to excitations represented by their Fourier series. Fourier coefficients for functions of linear segments. Exponential form of the Fourier series. Discrete Fourier analysis. Fast Fourier Transform (FFT).

Specific objectives:
Identify the family of harmonics as a basis of functions to represent periodic functions. Understand that the response to a periodic function is the linear combination of responses to the component harmonic functions previously calculated in a Fourier analysis. Be able to develop a Fourier analysis and obtain the corresponding response in the frequency domain. Know the response to excitations represented by their Fourier series. Identify and know the need for Fourier coefficients for functions of linear segments constructed from discrete measurements. Know the development of the exponential form of the Fourier series. Know the procedure to follow to apply discrete Fourier analysis. Describe the basics of the fast Fourier transform (FFT).

Full-or-part-time: 3h
Theory classes: 3h

Topic 7. Rayleigh method

Description:
Rayleigh method. Generalized coordinates and the principle of virtual jobs. Generalized systems of one degree of freedom - rigid solids and solids with distributed elasticity. Rayleigh method. Modified Rayleigh method. Structural walls.

Specific objectives:
Be able to present the Rayleigh method from the principle of virtual work. Describe generalized systems of one degree of freedom - rigid solids and solids with distributed elasticity.

Full-or-part-time: 1h
Theory classes: 1h

Topic 8. Non linear response

Description:
Nonlinear structural response. Geometric nonlinearity and material nonlinearity. Nonlinear model with one degree of freedom. Integration of the nonlinear equation of motion. Step by step method. Linear acceleration. Elastoplastic behavior. Algorithm to solve elastoplastic systems.

Specific objectives:
Identify nonlinear structural behavior and ability to differentiate geometric nonlinearity and material nonlinearity. Know the integration of the nonlinear equation of motion. Know the algorithm of the method step by step.

Full-or-part-time: 2h
Theory classes: 2h

Topic 9. Seismic spectra

Description:
Spectral response. Definition and construction of the spectral response. Spectral response for base motion. Spectral relationships. Tripartite spectral response. Elastic design and spectral response. Spectral response for non-elastic systems. Spectral response for non-elastic design.

Specific objectives:
Define and correctly interpret the spectral response. Be able to draw the spectral response. Be able to obtain the spectral response for the movement of the base. Deduce the spectral relationships. Know tripartite spectral response diagrams. Know the spectral response for non-elastic systems.

Full-or-part-time: 2h
Theory classes: 2h

Topic 10. Multiple degree of freedom systems. Modelling of simple buildings. Free vibration.

Description:
Structures modeled as simple buildings. The simple building. Stiffness equations. Free vibration of a simple building. Natural frequencies and normal modes. Orthogonality property of normal modes.

Specific objectives:
Know the definition of shear buildings. Be able to model shear buildings. Obtain the stiffness equations of a shear building. Be able to correctly define and construct the mass matrices and the stiffness matrix of a shear building. Ability to analyze the free vibration of a simple building and calculate the natural frequencies and normal modes. Recognize the problem as an algebraic problem of characteristic values. Know and deduce the orthogonality property of the normal modes of a shear building.

Full-or-part-time: 2h
Theory classes: 2h

Topic 11. Forced movement of a simple building

Description:
Forced movement of simple buildings Modal superposition method. Response to base movement.

Specific objectives:
Know the definition of forced movement of simple buildings. Ability to calculate the response based on the modal superposition method. Ability to calculate the response to base movement.

Full-or-part-time: 2h
Theory classes: 2h

Topic 12. Damped movement of a simple building

Description:
Damped movement of simple buildings. Equations for a simple building with damping. Decoupled equations with damping. Conditions for decoupling the equations of a damped system.

Specific objectives:
Description, approach and resolution of the equations for a simple building with damping. Know the conditions to decouple the equations of a damped system.

Full-or-part-time: 1h
Theory classes: 1h

Topic 13. Reduction of systems

Description:
Dynamic matrix reduction. Static condensation. Application to dynamic problems. Dynamic condensation.

Specific objectives:
Ability to formulate dynamic matrix reduction. Construction of static condensation. Know and describe its application to dynamic problems. Formulation of dynamic condensation.

Full-or-part-time: 2h
Theory classes: 2h

Topic 14. Random vibrations

Description:
Statistical description of a random function. Normal distribution. Rayleigh distribution. Correlation. Fourier transformation. Spectral analysis. Spectral density function. Narrow and wide band random processes. Response to random vibrations.

Specific objectives:
Capacity to process random functions.

Full-or-part-time: 1h
Theory classes: 1h

Topic 15. The seismic standard

Description:
The earthquake-resistant standard. Seismic danger. The land. Calculation acceleration. Normalized spectra. Calculation of spectra in a specific location. Example of spectrum calculation. Structural response calculation methods. Application examples.

Specific objectives:
Basic knowledge of the earthquake-resistant standard and the Eurocode. Identification of the most relevant parameters. Ability to describe seismic danger as provided by the standard. Describe the formula to obtain the calculation acceleration from the basic acceleration. Understand the effects of the terrain and the parameter that quantifies them. Calculate normalized spectra from local parameters. Calculation of spectra in a specific location. Know the dynamic calculation methods included in the standard. Ability to apply the simplified method to a calculation of a conventional structure.

Full-or-part-time: 3h
Theory classes: 3h

ACTIVITIES

Practice 1. One degree of freedom systems.

Description:
One degree of freedom systems in free vibration. Natural frequency. Framed structures. One degree of freedom systems under external loads. Transient response and permanent response. Resonance. Dynamic amplification. Transmissibility.

Material:
Python and Matlab

Delivery:
Writing software codes (commented) and application to exercises.

Full-or-part-time: 2h
Laboratory classes: 2h

Practice 2. Fourier analysis.

Description:
Programming for calculating Fourier spectra and power spectral densities.

Material:
Python and Matlab.

Delivery:
Writing software codes (commented) and application to exercises.

Full-or-part-time: 2h
Laboratory classes: 2h

Practice 3. Seismic spectra

Description:
Seismic databases. Selection and preprocessing of accelerograms. Baseline correction, interpolation and extrapolation. Arias intensity. Calculation of seismic spectra corresponding to specific accelerograms.

Material:
Python and Matlab.

Delivery:
Writing software codes (commented) and application to exercises.

Full-or-part-time: 2h
Laboratory classes: 2h

Practice 4. Dynamic analysis

Description:
Dynamic analysis of structures. Duhamel integral. Numerical methods of analysis.

Material:
Python and Matlab

Delivery:
Writing software codes (commented) and application to exercises.

Full-or-part-time: 2h
Laboratory classes: 2h

Practice 5. Simple building

Description:
Damped motion of simple building. Solving equations of motion.

Material:
Python and Matlab

Delivery:
Writing software codes (commented) and application to exercises.

Full-or-part-time: 2h
Laboratory classes: 2h

Practice 6. Application of the Seismic Standard

Description:
Calculation of structural performance using simplified methodologies of the earthquake-resistant standard.

Material:
Python and Matlab

Delivery:
Writing software codes (commented) and application to exercises.

Full-or-part-time: 2h
Laboratory classes: 2h

GRADING SYSTEM

Partial evaluation 1 (15%)
Partial evaluation 2 (15%)
Internships (40%)
Final Exam (30%)

BIBLIOGRAPHY

Basic:
- Paz, M. Dinámica Estructural. Barcelona: Reverté, 1992.
- Clough, RW and Penzien, J. Dynamics of Structures. New York: Mc Graw-Hill, 1975.
- Chopra, Anil K.. Dynamics of structures. Theory and applications to earthquake engineering. New Jersey: Prentice Hall, 2001.
- Chapra, Steven C. Métodos Numéricos aplicados con Matlab. 5ª. Mexico: Mc Graw-Hill, 2023. ISBN 978-1-4562-9494-6.
- Barbat, AH y Miquel Canet, J. Estructuras sometidas a acciones sísmicas. Barcelona: CIMNE, 1994.