# Structural Dynamics (250704)

## General information

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| **School:** | ETSECCPB |
| **Departments:** | Departament d'Enginyeria Civil i Ambiental (DECA) |
| **Credits:** | 5.0 ECTS |
| **Programs:** | MÀSTER UNIVERSITARI EN ENGINYERIA ESTRUCTURAL I DE LA CONSTRUCCIÓ, pla 2015 - (codi pla 1140) |
| **Course:** | 2015/2016 |
| **Course language:** | Castellano |

## Faculty

Responsible faculty: Sergio Horacio Oller Martinez

Teachers: Rolando Antonio Chacón Flores, Sergio Horacio Oller Martinez

## Generic objectives

Subject to acquire knowledge and skills to understand and solve dynamic problems in structures

Capability to understand and solve problems of dynamics in structures. Ability to consider the dynamics in structural design .

Basic concepts of structural dynamics. Dynamic models with a single degree of freedom and with several degrees of freedom. Formulation of the equation of motion . Formulation of the equation of motion and dynamic response of a system with "n " degrees of freedom : Lagrangeanas or generalized coordinates . Introduction to the dynamics of nonlinear structures

The aim of this course is to get students to acquire knowledge and skills to understand and solve problems of dynamic structures and is trained to consider the dynamics in the structural design. This course will lay the foundation for further studies of structures subjected to seismic actions, wind and vibrations caused by machines in general and trafficking.

## Skills

### *Specific skills*

To conceive and design civil and building structures that are safe, durable, functional and integrated into its surroundings.

Designing and building using traditional materials (reinforced concrete, prestressed concrete, structural steel, masonry, wood) and new materials (composites, stainless steel, aluminum, shape memory alloys?).

Mathematically modelling  structural engineering problems.

To apply methods and advanced design software and structural calculations, based on knowledge and understanding of forces and their application to the structural types of civil engineering.

***Generic skills of subject***

To conceive, design, analyze and manage structures or structural elements of civil engineering or building, encouraging innovation and the advance of knowledge.

To develop, improve and use conventional materials and new construction techniques to ensure the safety requirements, functionality, durability and sustainability.

## ECTS credits: total hours of student work

| | | Dedication | |
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| | | **Hours** | **Percent** |
| **Supervised Learning** | **Theory** | 20.50 | 45.6% |
| | **Assignments** | 13.50 | 30.0% |
| | **Laboratory** | 11.00 | 24.4% |
| | **Supervised activities** | 0.00 | 0.0% |
| **Self-Learning** | | 105.00 | |

## Contents

***Basis of structural dynamics***

***Dedication***

3.0h. Theory

***Description***

- Introduction. - Definition of the dynamic action: deterministically, stochastically. - Structures and structural models. - Methods of dynamic modeling. Spatial discretization of the structures. Method of concentrated masses. Widespread displacement method. Finite element method. - Dynamic Models: A one degree of freedom; A multiple degrees of freedom.

***Formulation of the equation of motion. Dynamic response of a system of 1 DoF***

***Dedication***

5.5h. Theory + 5.5h. Assignments + 8.0h. Laboratory

***Description***

- Introduction and overview of the dynamic behavior of buildings. -Formulation Of the equations of motion. Principle of D'Alembert. Widespread displacement principle or virtual displacements. Hamilton functional.

- Equation of motion of a system with one degree of freedom.

- Pseudo spectra and response spectra of an oscillator to a degree of freedom.

- Numerical solution of the integral of the response spectra. - Using the response spectrum in the calculation of a structure, correction of the spectra, normalization of spectra, representing Newmark, approximate construction of response spectra.

- Vibrations in structures produced by traffic and noise ratio. Frequency filters and noise attenuation structures.

- Analysis in the frequency domain. Forward and reverse transformation. Fast Fourier Transform. Response spectra and amplitudes of Fourier spectra.

Problem Classes. ASSESSED (70% of grade). Delivery dates mentioned in each case. - Work Problem 1: Calculation of frequencies 1GL simple structures. - Work Issues 2: dynamic time response 1GL simple structures. Harmonic actions. - Work Problem 3: dynamic time response 1GL simple structures. Any actions. I work Problem 4: Dynamic Frequency response - Fourier Transforms. - Work Problem 5: pseudo-spectra and theoretical spectra.

Laboratory classes. ASSESSED (30% of grade). The work is done and delivered on the same day on the date mentioned in each case.

- Laboratory Work 1: Introduction to experimentation. Introduction to computers. Introduction to mounting connections Introduction to data acquisition. Compare Arduino and Traditional measurements.

- Laboratory Work 2: Study of damped free vibrations. Cantilevered strip. It will be done with Arduino for different beam lengths for each student. Initially, Arduino-Spider comparisons will be made to show the ability of low-cost items.

- Laboratory Work 3: Study of damped forced vibrations. Cantilevered strip. It will be done with Arduino for different beam lengths for each student.

***Formulation of the equation of motion. Dynamic response of a system with N DoF***

***Dedication***

7.0h. Theory + 7.0h. Assignments + 2.0h. Laboratory

***Description***

- Introduction and overview of the dynamic behavior of buildings. Lagrangeanas or generalized coordinates.

- Continuous models. Virtual work. Beam bending vibration. Solution of the equation of motion for free vibration. Natural frequencies and normal modes for uniform beams. Orthogonality condition between normal modes. Introduction to the concept of discretization.

- Simple models with varying degrees of freedom. Building shear. Gantry general model. Finite element model.

- Resolution by reducing the number of degrees of freedom. Rough or lateral condensation. Exact condensation or dynamic.

- Formulation of the differential equation of motion from the first law of thermodynamics. Formulation from the primal energy potential. Minimizing the potential primal energy. Application to discrete solid

- Finite Element -. Elementary domain. Global domain. - Functional Hamilton and formulation of the differential equation of motion for a system with "n" degrees of freedom. Equation of motion for a generalized coordinate any. Equation of motion of a solid to the "n" generalized coordinates.

- Modal response analysis I: undamped free oscillation of a system to "n" degrees of freedom.

- Obtaining the modal parameters, overlapping system response -. Undamped forced oscillation of a system to "n" degrees of freedom. Forced damped oscillation of a system to "n" degrees of freedom.

- Calculation of eigenvalues and eigenvectors through simple methods: Rayleigh, Stodola Vianello and also through numerical methods: direct, iterative.

- Modal response analysis II: damped oscillation of a system to "n" degrees of freedom under the action of an earthquake.

- Analysis of the response in the history of time. Spectral analysis of the response. Calculation of shear buildings. Structures modeled as plane frames.

- Numerical analysis time by a step of integrating the equation of motion: Direct methods. Taylor series approximation. Central differences. Houbolt back or differences. Newmark method. Wilson method.

Problem Classes. ASSESSED (70% of grade). Delivery dates mentioned in each case.

- Work Issues 6: Fundamental frequency in continuous structures.

- Work Issues 7: structural "N" GL Systems. Shear frame structure

Laboratory classes. ASSESSED (30% of grade). The work is done and delivered on the same day on the date mentioned in each case.

- Laboratory Work 4: Session Programming in Matlab, Python, VisualBasic or another language.

- Laboratory Work 5: Shear frame structure.

### *Introduction to the dynamics of non-linear structure*

***Dedication***

5.0h. Theory + 1.0h. Assignments + 1.0h. Laboratory

***Description***

- Simplified representation of the nonlinear behavior of an oscillator: inertial nonlinearity, damping non-linearity, nonlinearity of stiffness: constitutive and geometric. Ductility of a nonlinear oscillator degree of freedom.

- Inelastic response spectrum: ductility required spectrum, spectrum coefficient project, effective reduction of forces.

- Formulation of dynamic equilibrium for a structure subjected to nonlinear behavior.

- Linearization of the equilibrium equation.

- Various nonlinear effects in structures caused by nonlinear dynamic actions

- Solving the equation of motion in structures subjected to non-linear behavior.

- Explicit-Implicit Solution.

- Introduction to material behavior models, independent of time (damage, plasticity). Effects on the structural behavior.

- Introduction to the models of material behavior, time dependent (viscoelasticity, viscoplasticity, viscodamage). Effects on the structural behavior. The structural damping and its origin in the material.

- Evolution of the natural frequency of structures subjected to dynamic actions. Relationship between the change of natural frequency and structural damage.

Problem Classes. ASSESSED (70% of grade). Delivery dates mentioned in each case.

- Work Issues 8: nonlinear structural systems. Inelastic spectra. Ductility

## Activities

## Grading rules (*)

***(*) The evaluation calendar and grading rules will be approved before the start of the course.***

The course grade is derived from the ratings of ongoing evaluation issues and related laboratory and / or computer room.

The course grade is the average of the notes of problems and laboratory work presented.

Work problems were made using tools like MathCad and / or Matlab and / or finite element programs developed by students and other programs that will be provided as a model.

Laboratory work were carried out with the aid of digital sitemas Open-Cod (Arduino)

## Test rules

Failure to perform a laboratory or continuous assessment activity in the scheduled period will result in a mark of zero in that activity.

## Teaching methodology

This course takes place in 34 hours of theory and problems, 8 hours of laboratory systems using Open-Code (Arduino) and 5 hours of supervised work for 14 weeks. Also, the student must devote 63 hours to learn and solve problems that demand this subject. In particular there will be 7 practical work on basic issues and also on some structures, and 5 laboratory work. Both laboratory work and the problems should be solved by the student individually and delivered for evaluation.

The work will be carried problem with MathCad codes, and / or Matlab, and / or Fortran.

Laboratory work was conducted with the help of Code of Arduino Open-type devices, which allow students to design and program their own measuring devices.

Support material is used in the form of detailed teaching plan using the virtual campus ATENEA: content, programming and evaluation activities directed learning and literature.

## Office hours

At the end of each class

## Basic bibliography


- Barbat, S. Oller. **Conceptos de cálculo de estructuras en las normativas de diseño sismorresistente** . CIMNE IS-24. 1997.
- A. Barbat, S. Oller, J. C Vielma. **Cálculo y diseño sismorresistente de edificios. Aplicación de la norma NCSE-02**. CIMNE IS-56. 2005.
- A. Barbat, J. Miquel. **Estructuras sometidas a acciones sísmicas**. CIMNE. 1994.
- S. Oller. **Nonlinear dynamics of structures**. Springer. 2014.
- E. Blanco, S. Oller, L. Gil. **Análisis Experimental de Estructuras**. CIMNE. 2009.
- M. paz. **Dinámica estructural**. Reverte. 1992.
- F. Cesari. **Metodi di calcolo nella dinamica delle struttur**. Pitagora Bologna . 1982.
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- A. K. Chopra. **Dynamics of Structures. - A. K. Chopra. Dynamics of Structures, Theory and Application to Earthquake Engineering**. Prentice Hall. 2007.


## Complementary bibliography


- I. Chowdhury, S. P. Dasgupta. Dynamics of Structure and Foundation– A Unified Approach.. CRC Press/Balkema. 2009.
- S. Timoshenko. **Vibration problems in Engineering**. Van Nostrand Company. 1937.
- C. E. Hanson, D. A. Towers, and L. D. Meister. **Transit Noise and Vibration Impact Assessment.** . U.S. Department of Transportation Federal Transit Administration Office of

Planning and Environment. FTA-VA-90-1003-06. 2006.