ANX-PR/CL/001-01

LEARNING GUIDE

SUBJECT

43000439 - Dynamic And Seismic Analysis Of Structures

DEGREE PROGRAMME

04AM - Master Universitario Ingenieria De Estructuras, Cimentaciones Y Materiales

ACADEMIC YEAR & SEMESTER

2022/23 - Semester 2

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1. Description

1.1. Subject details

Name of the subject	43000439 - Dynamic And Seismic Analysis Of Structures
No of credits	4.5 ECTS
Type	Optional
Academic year ot the programme	First year
Semester of tuition	Semester 2
Tuition period	February-June
Tuition languages	English
Degree programme	04AM - Master Universitario Ingenieria de Estructuras, Cimentaciones y Materiales
Centre	04 - Escuela Tecnica Superior De Ingenieros De Caminos, Canales Y Puertos
Academic year	2022-23

2. Faculty

2.1. Faculty members with subject teaching role

Name and surname	Office/Room	Email	Tutoring hours *
Carlos Martin De La Concha Renedo	Lab. Estruct.	carlos.martindelaconcha@upm.es	Th - 11:00 - 12:00 F - 11:00 - 12:00
Ivan Muñoz Diaz (Subject coordinator)	Lab. Estruct.	ivan.munoz@upm.es	W - 11:00 - 14:00 Th - 11:00 - 14:00 Laboratorio de Estructuras, Level -2

Jose Manuel Soria Herrera	Floor 9	jm.soria@upm.es	Th - 11:30 - 13:30 Laboratorio de Estructuras, Level -2
Carlos Zanuy Sanchez	Lab. Estruct.	carlos.zanuy@upm.es	Th - 11:00 - 14:00 F - 11:00 - 14:00 Laboratorio de Estructuras, Level -2

* The tutoring schedule is indicative and subject to possible changes. Please check tutoring times with the faculty member in charge.

2.2. Research assistants

Name and surname	Email	Faculty member in charge
Barrera Vargas, Christian Alexander	christian.barrera@upm.es	Muñoz Diaz, Ivan

3. Prior knowledge recommended to take the subject

3.1. Recommended (passed) subjects

- Elementos Finitos

3.2. Other recommended learning outcomes

- Static analysis of structures

- MATLAB programming skills

- Ordinary Differential equations, partial differential equations, vector, matrices and linear algebra

- Mechanical vibrations

- Steel and concrete structure design

4. Skills and learning outcomes *

4.1. Skills to be learned

CB10 - Que los estudiantes posean las habilidades de aprendizaje que les permitan continuar estudiando de un modo que habrá de ser en gran medida autodirigido o autónomo.

CB6 - Poseer y comprender conocimientos que aporten una base u oportunidad de ser originales en el desarrollo y/o aplicación de ideas, a menudo en un contexto de investigación

CB9 - Que los estudiantes sepan comunicar sus conclusiones y los conocimientos y razones últimas que las sustentan a públicos especializados y no especializados de un modo claro y sin ambigüedades

CE13 - - Capacidad para el ejercicio profesional de alta especialización o para la investigación predoctoral mediante la utilización de recursos de modelización predictiva en Análisis y diseño estructural en régimen dinámico y/o no lineal.

CG1 - Polivalencia para extender a ámbitos afines las competencias generales adquiridas en el ámbito temático del título.

CG4 - Capacidad de comunicación académica de contenido técnico y científico, oral y escrita en lengua inglesa.

CG5 - Capacidad de utilización de los servicios de comunicación y de obtención de información para su transformación en conocimiento aplicable al ejercicio de las competencias específicas.

CT3 - Compromiso y capacidad de aplicación de los estándares de deontología en investigación y ejercicio profesional avanzado

4.2. Learning outcomes

RA17 - conocer los fundamentos físicos de los comportamientos macroscópicos

RA23 - Conoce la influencia de las diversas causas de no linealidad en el análisis dinámico de estructuras y los métodos de cálculo aplicables.

RA7 - Diseña, analiza e interpreta experimentos relevantes en ingeniería estructural, geotécnica y de materiales estructurales

RA18 - saber aplicar los conocimientos anteriores en diseño, construcción y mantenimiento de estructuras

RA20 - Conoce las causas de no linealidad geométrica en estructuras y los métodos de cálculo en los distintos niveles.

RA9 - Participa en debates en lengua inglesa

RA6 - Aplica normativa europea e internacional de ingeniería estructural, geotécnica y de materiales estructurales en proyecto, construcción, conservación y evaluación técnica

RA15 - Aplica normativa europea e internacional de ingeniería estructural, geotécnica y de materiales estructurales en proyecto, construcción, conservación y evaluación técnica Interioriza los principios de deontología profesional de ingeniería civil

RA8 - Utiliza con eficacia recursos de modelización predictiva en una o más de las materias del módulo

RA2 - Presenta comunicaciones orales, escritas y gráficas, estructurada y argumentadamente, en lengua española e inglesa

RA13 - Sintetiza e integra con polivalencia y autonomía las competencias específica de formación científico-técnica para iniciación en I+D+i, para la alta especialización y para la investigación doctoral.

* The Learning Guides should reflect the Skills and Learning Outcomes in the same way as indicated in the Degree Verification Memory. For this reason, they have not been translated into English and appear in Spanish.

5. Brief description of the subject and syllabus

5.1. Brief description of the subject

This subject introduces students to the fundamentals and techniques of structural dynamics and their applications in the design and analysis of civil structures subjected to dynamic loadings, such as earthquakes or human-induced vibrations.

Upon the completion of this course, students are expected to be able to:

- understand the nature of dynamic loading (time-varying loads), with emphasis on human-induced vibrations and earthquakes loads,
- derive reasonable engineering model since simplified models to finite element models,
- obtain/quantify the response of civil engineering structures to such loads,
- apply structural design approaches incorporating structural dynamics for both strength and serviceability requirement using European standards,
- understand and design strategies to mitigate vibrations, and
- assess the dynamic response of structures experimentally.

5.2. Syllabus

1. Dynamic Problems

   1.1. Course presentation. Motivation of dynamic analysis. Theoretical and experimental vibration analysis.

   1.2. Vibrations problems in structures.

2. Single-degree-of-freedom systems

   2.1. Degrees of freedoms. Examples of 1DOF.

   2.2. Shear building. Stiffness and mass matrix. Static condensation.

   2.3. Undamped vibration. Damped vibrations. Logarithmic decrement.

   2.4. Harmonic response.

   2.5. Frequency-response-function Method. Modal Parameter extraction.

   2.6. MATLAB introduction and single-degree of freedom examples.

3. Two-degree-of-freedom systems

3.1. Two-story shear building. Modal analysis. Modal superposition. Mode normalization.

3.2. Structural control. Tuned vibration absorbers: undamped and damped.

3.3. Practice on tuned vibration absorbers, in situ measurements and vibration serviceability assessment. Oral presentation.

4. Multi-degree-of-freedom systems

4.1. Continues and discrete systems. Truncated systems.

4.2. Modal superposition method.

4.3. Damping. Modal damping. Rayleigh damping.

4.4. Direct integration: explicit and implicit methods.

4.5. Harmonic response and Frequency-response-function method.

4.6. State-space representation and energy balance.

4.7. Continuous systems: Beam vibrations.

4.8. Equivalent single-degree-of-freedom systems.

4.9. Practice on a multi-story shear building, state-space representation.

4.10. Practice on a commercial FEM suite of software: modal and transient analyses.

5. Vibration Isolation

5.1. Vibration isolation of rigid bodies. Transmissibility.

5.2. Vibration isolation of flexible structures. Linear isolator. Friction Pendulum systems.

5.3. 6.3. Practice on isolation of a flexible structure.

6. Experimental tests

6.1. 7.1. Introduction to instrumentation for dynamic analysis.

6.2. Experimental calculation of frequency response function.

6.3. 7.2. Lab practice on an example of an instrumented structure.

7. Seismic Analysis: Spectrum analysis

7.1. The seismic load: design spectrum versus artificial accelerograms.

7.2. Modal spectral analysis.

7.3. Transient analysis based on artificial accelerograms.

7.4. Equivalent force analysis.

7.5. Earthquake resistant design.

7.6. Practice on a commercial FEM suite of software: modal spectral analysis versus transient analysis.

8. Seismic analysis: inelastic analysis

8.1. Inelastic response.

8.2. Modal pushover analysis.

8.3. Lab practice on a seismic table test.

8.4. Practice on a commercial FEM suite of software: modal pushover analysis.

8.5. Seismic protection of structures using passive control systems.

8.6. Performance-based design.

8.7. Practice on a commercial FEM suite of software: passive control of a shear building under earthquake action.

9. Seismic codes

9.1. Spanish Earthquake- Construction Code for buildings NCSE-02 and bridges NCSP-07.

9.2. Eurocode 8.

9.3. Construction details: ductility and damping.

9.4. Practice on a commercial FEM suite of software: Comparative analysis of the dynamic response of a shear building in terms of the considered construction details.

6. Schedule

6.1. Subject schedule*

Week	Classroom activities	Laboratory activities	Distant / On-line	Assessment activities
1	**Unit 1. Dynamic Problems** Duration: 02:00 Lecture **Unit 2. Single-degree-of-freedom systems** Duration: 01:00 Lecture		**Unit 1. Dynamic Problems** Duration: 02:00 Lecture **Unit 2. Single-degree-of-freedom systems** Duration: 01:00 Lecture	
2	**Unit 2. Single-degree-of-freedom systems** Duration: 03:00 Lecture		**Unit 2. Single-degree-of-freedom systems** Duration: 03:00 Lecture	
3	**Unit 2. Single-degree-of-freedom systems** Duration: 01:00 Problem-solving class	**Unit 2. MATLAB introduction. Single-degree-of-freedom examples** Duration: 02:00 Laboratory assignments	**Unit 2. MATLAB introduction. Single-degree-of-freedom examples** Duration: 02:00 Laboratory assignments	**Resolution and submission of assigned tasks (exercises and case-studies) during the course. The assignments wil mainly include practical exercises based on the lectures and laboratory classes.** Individual work Continuous assessment Not Presential Duration: 08:00
4	**Unit 3. Two-degree-of-freedom systems** Duration: 03:00 Lecture		**Unit 3. Two-degree-of-freedom systems** Duration: 03:00 Lecture	
5	**Unit 3. Two-degree-of-freedom systems** Duration: 01:00 Problem-solving class	**Unit 3. Practice on tuned vibration absorbers, in situ measurements and vibration serviceability assessment. Oral presentation** Duration: 02:00 Laboratory assignments	**Unit 3. Two-degree-of-freedom systems** Duration: 01:00 Problem-solving class **Unit 3. Alternative Practice on tuned vibration absorbers. Oral presentation** Duration: 02:00 Laboratory assignments	**Resolution and submission of assigned tasks (exercises and case-studies) during the course. The assignments will mainly include practical exercises based on the lectures and laboratory classes.** Group work Continuous assessment Not Presential Duration: 12:00
6	**Unit 4. Multi-degree-of-freedom systems** Duration: 03:00 Lecture		**Unit 4. Multi-degree-of-freedom systems** Duration: 03:00 Lecture	
7	**Unit 4. Multi-degree-of-freedom systems** Duration: 01:00 Lecture	**Unit 4. Practice on a multi-story shear building, state-space representation** Duration: 02:00 Laboratory assignments	**Unit 4. Multi-degree-of-freedom systems** Duration: 01:00 Lecture **Unit 4. Practice on a multi-story shear building, state-space representation** Duration: 02:00 Laboratory assignments	

8	**Unit 5. Vibration isolation** Duration: 01:00 Lecture	**Unit 4. Practice on a commercial FEM suite of software: modal and transient analyses.** Duration: 02:00 Laboratory assignments	**Unit 4. Practice on a commercial FEM suite of software: modal and transient analyses.** Duration: 02:00 Laboratory assignments **Unit 5. Vibration isolation** Duration: 01:00 Lecture	
9	**Unit 6. Experimental tests** Duration: 02:00 Lecture	**Unit 5.Practice on isolation of a flexible structure** Duration: 01:00 Laboratory assignments	**Unit 5.Practice on isolation of a flexible structure** Duration: 01:00 Laboratory assignments **Unit 6. Experimental tests** Duration: 02:00 Lecture	**Resolution and submission of assigned tasks (exercises and case-studies) during the course. The assignments will mainly include practical exercises based on the lectures and laboratory classes.** Individual work Continuous assessment Not Presential Duration: 12:00
10	**Unit 6. Experimental tests** Duration: 01:00 Problem-solving class	**Unit 6. Lab practice on an example of an instrumented structure** Duration: 02:00 Laboratory assignments	**Unit 6. Experimental tests** Duration: 01:00 Problem-solving class **Unit 6. Alternative practice** Duration: 02:00 Laboratory assignments	**Resolution and submission of assigned tasks (exercises and case-studies) during the course. The assignments will mainly include practical exercises based on the lectures and laboratory classes.** Individual work Continuous assessment Not Presential Duration: 08:00
11	**Unit 7. Seismic Analysis: Spectrum analysis** Duration: 02:00 Lecture **Unit 7. Seismic Analysis: Spectrum analysis** Duration: 01:00 Problem-solving class		**Unit 7. Seismic Analysis: Spectrum analysis** Duration: 02:00 Lecture **Unit 6. Lab practice on an example of an instrumented structure** Duration: 02:00 Laboratory assignments	
12	**Unit 8. Seismic analysis: inelastic analysis** Duration: 01:00 Lecture	**Unit 7. Practice on a commercial FEM suite of software: modal spectral analysis versus transient analysis** Duration: 02:00 Laboratory assignments	**Unit 7. Practice on a commercial FEM suite of software: modal spectral analysis versus transient analysis** Duration: 02:00 Laboratory assignments **Unit 8. Seismic analysis: inelastic analysis** Duration: 01:00 Lecture	
13	**Unit 8. Seismic analysis: inelastic analysis** Duration: 01:00 Problem-solving class	**Unit 8. Practice on a commercial FEM suite of software: modal pushover analysis.** Duration: 02:00 Laboratory assignments	**Unit 8. Seismic analysis: inelastic analysis** Duration: 01:00 Problem-solving class **Unit 8. Practice on a commercial FEM suite of software: modal pushover analysis.** Duration: 02:00 Laboratory assignments	

14	**Unit 9. Seismic codes** Duration: 02:00 Lecture	**Unit 8. Lab practice on a seismic table test** Duration: 02:00 Laboratory assignments	**Unit 9. Seismic codes** Duration: 01:00 Lecture **Unit 8. Alternative practice** Duration: 02:00 Laboratory assignments	
15	**Unit 9. Seismic codes** Duration: 02:00 Lecture	**Unit 9. Practice on a commercial FEM suite of software: Comparative analysis of the dynamic response of a shear building in terms of the considered construction details.** Duration: 01:00 Laboratory assignments	**Unit 9. Seismic codes** Duration: 02:00 Lecture **Unit 9. Practice on a commercial FEM suite of software: Comparative analysis of the dynamic response of a shear building in terms of the considered construction details.** Duration: 01:00 Laboratory assignments	**Resolution and submission of assigned tasks (exercises and case-studies) during the course. The assignments wil mainly include practical exercises based on the lectures and laboratory classes.** Group work Continuous assessment Not Presential Duration: 20:00
16				
17				**Preparation of the Final Exam** Individual work Continuous assessment Not Presential Duration: 10:00 **Final Exam. Ordinary Evaluation** Written test Continuous assessment Presential Duration: 03:00

Depending on the programme study plan, total values will be calculated according to the ECTS credit unit as 26/27 hours of student face-to-face contact and independent study time.

* The schedule is based on an a priori planning of the subject; it might be modified during the academic year, especially considering the COVID19 evolution.

7. Activities and assessment criteria

7.1. Assessment activities

7.1.1. Assessment

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
3	Resolution and submission of assigned tasks (exercises and case-studies) during the course. The assignments wil mainly include practical exercises based on the lectures and laboratory classes.	Individual work	No Presential	08:00	5%	0 / 10	CB10 CE13 CG1
5	Resolution and submission of assigned tasks (exercises and case-studies) during the course. The assignments will mainly include practical exercises based on the lectures and laboratory classes.	Group work	No Presential	12:00	10%	0 / 10	CB6 CB9 CB10 CT3 CE13 CG1 CG4 CG5
9	Resolution and submission of assigned tasks (exercises and case-studies) during the course. The assignments will mainly include practical exercises based on the lectures and laboratory classes.	Individual work	No Presential	12:00	10%	0 / 10	CB10 CE13 CG1
10	Resolution and submission of assigned tasks (exercises and case-studies) during the course. The assignments will mainly include practical exercises based on the lectures and laboratory classes.	Individual work	No Presential	08:00	5%	0 / 10	CB6 CT3 CE13
15	Resolution and submission of assigned tasks (exercises and case-studies) during the course. The assignments wil mainly include practical exercises based on the lectures and laboratory classes.	Group work	No Presential	20:00	10%	0 / 10	CB6 CB9 CB10 CT3 CE13 CG1 CG5

17	Preparation of the Final Exam	Individual work	No Presential	10:00	0%	0 / 10	
17	Final Exam. Ordinary Evaluation	Written test	Face-to-face	03:00	60%	0 / 10	CB6 CB9 CT3 CE13 CG1 CG4 CG5

7.1.2. Global examination

No se ha definido la evaluacion sólo por prueba final.

7.1.3. Referred (re-sit) examination

Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
Those students with a score less than 5 after the final exam will have another opportunity in the second-period examination (extraordinary). The final Extraordinary Exam corresponds to 60% of the final mark.	Written test	Face-to-face	03:00	60%	/ 10	CB6 CB9 CT3 CE13 CG1 CG4 CG5

7.2. Assessment criteria

EM1. Student's work, 40 %
Description: Resolution and submission of assigned tasks during the course. Evaluation criteria: The assignments will be ranked from 0 to 10 as a result of the weighted average of the results obtained in the tasks. Weights will be according to the difficulty and work required by the exercises. Place and period: The submission system will be available into the Moodle platform. The tasks will be announced and carried out during the course. In case that the laboratory practices would have to be Not Presential, they will be substitute by numerical practices.

EM2. Final Exam, 60 %
Description: The final exam will contain applied theory and practical exercises. Evaluation criteria: The final exam will be ranked from 0 to 10. Place and period: Place, period and technical details will be taken from the procedures set by the Head of Studies. In case that the Final Exam would have to be Not Presential, it would be carried out through Moodle platform.
Result of the evaluation
The final score will be the weighted average of the results obtained in EM1 and EM2 according to the indicated weights. The subject will be passed if the final score is equal or greater than 5. Those students with a score less than 5 will not pass the subject and will have another opportunity in the second-period examination (extraordinary). This is applied to both Ordinary and Extraordinary Evaluation

8. Teaching resources

8.1. Teaching resources for the subject

Name	Type	Notes
Moodle platfom	Web resource	Lectures' presentations; Assignments for students; Recommended references
Laboratory of Structures	Equipment	Equipment and materials for laboratory classes
Computing room	Equipment	Laboratory clasess on numerical simulations
SAMCO Guideline	Bibliography	SAMCO Final Report 2006 F05 Guidelines for Structural Control
JRC-Scientific and Technical Report, 2009	Bibliography	Guideline. Design of Lightweight Footbridges for Human Induced Vibrations
ISO 101037:2007	Others	Standards. Bases for design of structures-Serviceability of buildings and walkways against vibrations

NCSE-02	Others	Standards. Norma de Construcción Sismorresistente Española para Edificación
NCSP-07	Others	Standards. Norma de Construcción Sismorresistente para Puentes (España)
EN 1998-1:2004	Others	Standards. Eurocode 8
Diaz, I.M., (2012)	Bibliography	Notes on Fundamentals of Dynamics of structures
Chopra, A.K., (2012)	Bibliography	Chopra, A.K. (2012): Dynamics of structures. Structures: Theory and Applications to Earthquake Engineering, Prentice Hall
Humar, J.L. (2012)	Bibliography	Humar, J.L. (2012): Dynamics of structures Prentice Hall.Graw-Hill International.
Bachmann et. al, (2005)	Bibliography	Vibration problems in structures: practical guidelines" (1995). Birkhäuser verlag.
Ger, J., Cheng, F.V., (2011)	Bibliography	Seismic Design Aids for Nonlinear Pushover Analysis of Reinforced Concrete and Steel Bridges (Advances in Earthquake Engineering)
Hadi, M., Uz, M.E., (2017)	Bibliography	Earthquake Resistant Design of Building
Fardis, M.N., (2010)	Bibliography	Advances in Performance-Based Earthquake Engineering
Takewaki, I., (2009)	Bibliography	Building Control with Passive Dampers: Optimal Performance?based Design for Earthquakes