Experimental Structural Analysis

1. General overview

UPM Code	Credits	Type	Specialization	Language
43000384	4,5	Optional	Structures, Geotechnics, Construction and Materials	English

Name in Spanish	Análisis Experimental de Estructuras
Subject	Option of Structures, Geotechnics, Construction and Materials
Department	Continuum Mechanics and Structures
Web page	http://ingstruct.mecanica.upm.es/node/7
Semester	Third semester

2. Teaching staff

Name	Evaluation jury	Group	Office hours	Place	E-mail address
Carlos Zanuy Sánchez	Chair	All	Thur & Fri, 11:00-14:00	Structures Lab.	*czs@caminos.upm.es*
Iván Muñoz Díaz	Secr.	All	Wed & -Thur, 11:00-14:00	Structures Lab.	*ivan.munoz@upm.es*
Rafael Fernández Díaz-Munío	Member	All	Mon & Thur, 10:30-13:30	Structures Lab.	*rfernandez@mecanica.upm.es*
Pablo de la Fuente Martín		All	Mon & Tue, 10:00-13:00	Tower, 6th	*pdelaf@caminos.upm.es*
Antonio Madrid Ramos		All	Thur, 10:30-13.30 Fri, 16:00-19.00	Structures Lab.	*antonio.madrid@upm.es*
Luis Plaza Beltrán		All	Mon & Fri, 15:30-18:30	Structures Lab.	*lplazabeltran@gmail.com*

NOTE. The person on the first place is the course coordinator.

3. Previous knowledge

Courses that must be taken in advance:

Other learning requirements:

4. Assigned competences

Code	Competence
CGP11	Ability to design, execute and inspect structures (bridges, buildings, etc), foundation Works and civil underground structures (tunnels, parkings), and evaluate their structural integrity.

Code	Competence
CE38	Ability to integrate and apply technical knowledge to all tasks related to assessment, maintenance, conservation, technical evaluation, exploitation, evaluation, planning, management and physical-mathematical modeling of environmental aspects affecting infrastructures.
CT1	Ability to prepare and present oral, written and graphical documents with order and clarity.
CT3	Capacity of technical communication in English, written and oral.
CT8	Ability to design, analyse and understand relevant experiments in civil engineering.

5. Student outcomes

Code	Learning results	Competences linked
SO1	The student knows the fundamentals and applications of the most relevant transducers for instrumentation of structures.	CGP11, CE38, CT1, CT3, CT8
SO2	The student acquires the fundamentals of static and dynamic experimental techniques in structural engineering, and understands the structural implications of taken measurements.	CGP11, CE38, CT1, CT3, CT8

6. Achievement indicators

Code	Basic	Indicators of achievement	SO linked
AI1	Yes	Correct definition of transducers and associated equipment to take static and dynamic measurements in a structure.	SO1
AI2	Yes	Adequate planning of methodology and required equipment to measurements in load tests and monitoring of structures and laboratory test.	SO1, SO2
AI3	Yes	Correct approach of experimental techniques to estimate the main mechanical properties of a structure.	SO2
AI4	Yes	Correct analysis of structural implications of experimental measurements taken in a structure.	SO2

NOTE. Basic: Indicator that must be achieved to pass the subject.

7. Evaluation methods and criteria

Code, name of evaluation methods, brief description of evaluation methods, criteria, place and period of evaluation	Weight

7.1. Evaluation through "continuous assessment"

EM1. Students' work **40%**

Description: Resolution of assigned tasks (exercises and case-studies) during the course. The tasks will be part of a student's notebook, available at the academic portal (Moodle). The student's notebook will mainly include practical exercises based on the lectures and laboratory classes.

Evaluation criteria: The student's notebook will be ranked from 0 to 10 as a result of the weighted average of the results obtained in the exercises and case-studies. Weights will be according to the difficulty and work required by the exercises.

Place and period: The student's notebook will be available at the academic portal (Moodle). The exercises and case-studies shall be completed according to the schedule and conditions announced during the course as the required knowledge are explained in the lectures.

Code, name of evaluation methods, brief description of evaluation methods, criteria, place and period of evaluation	Weight

EM2. Final exam **60%**

Description: The final exam will consist of two parts, with a duration of 1-1.5 hours each. The first part will consist of theoretical or applied questions. The second part will consist of two practical problems.

Evaluation criteria: The final exam will be ranked from 0 to 10. The first part will be ranked from 0 to 4 and each problem of the second part will be ranked from 0 to 2.

Place and period: To be determined by the Head of Studies

Result of the evaluation through "continuous assessment"

The final score will be the weighted average of the results obtained in PE1 and PE2 according to the indicated weights. It is required at least 3.5 points at each part to pass the subject by continuous assessment.

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).

7.2. Evaluation through "final exam only"

Description: The exam will be the same final exam done by the students under the evaluation through "continuous assessment" (PE2).

Evaluation criteria: The same as the one indicated above for the final exam PE2, thereby resulting in a score from 0 to 10.

Place and period: To be determined by the Head of Studies.

Result of the evaluation through "final exam only"

The final score will be the one obtained in the final exam.

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).

8. Course content

Units, sections and descriptors	Achievement indicators linked
Chapter I. Instrumentation	
Unit 1. Introduction to instrumentation	AI1
1.1. Definition	
1.2. Transducers. Types of transducers	
1.3. Characteristics of transducers	
Unit 2. Signal conditioning	AI1, AI2
2.1. Basics of Electrotechnics. Background	
2.2. Electric circuits in signal conditioning	
2.3. Signal amplification	
Unit 3. Strain measurements	AI1, AI2
3.1. Working principle of strain gages	
3.2. Configuration of strain gages	
3.3. Characteristics of strain gages	
3.4. Conditioning circuits for strain gages	
Unit 4. Load measurement	AI1, AI2
4.1. Load cells	
4.2. Equipments for load application	

Units, sections and descriptors	Achievement indicators linked
Unit 5. Displacement measurement **5.1.** Potentiometers **5.2.** Inductive transducers. LVDT **5.3.** Rotation measurement	AI1, AI2
Unit 6. Acceleration measurement **6.1.** Dynamic measurements **6.2.** Accelerometers. Definition and types	AI1, AI2
Chapter II. Load test	
Unit 7. Load tests in bridges **7.1.** Fundamentals and methodology **7.2.** Codes and standards	AI2
Unit 8. Load tests in buildings **8.1.** Fundamentals and methodology **8.2.** Codes and standards	AI2
Chapter III. Dynamic tests	
Unit 9. Frequency domain analysis **9.1.** Fourier analysis **9.2.** Single-degree-of-freedom systems **9.3.** Systems of multiple degree-of-freedoms **9.4.** Analysis of discrete signals	AI1, AI2
Unit 10. Equipments for dynamic analysis **10.1.** Key characteristics of equipments for dynamic measurements **10.2.** Types of excitation **10.3.** Transducers **10.4.** Data acquisition systems	AI1, AI2
Unit 11. In-service condition monitoring **11.1.** Analysis of measurements taken under in-service conditions **11.2.** In-service monitoring	AI3, AI4
Unit 12. Forced vibration analysis **12.1.** Theoretical analysis vs. Experimental analysis **12.2.** Estimation of frequency response functions **12.3.** Estimation of modal parameters **12.4.** Analysis of results and model updating	AI3, AI4
Unit 13. Operational modal analysis **13.1.** Comparison with forced vibration analysis **13.2.** Identification in the frequency domain **13.3.** Identification in the time domain	AI3, AI4
Unit 14. Case-studies	AI3, AI4

9. Description of teaching methodology

Theory lessons:

The teacher will explain the concepts necessary to understand the concepts of the course in order for the student to achieve the expected indicators. The teacher will use appropriate practical examples and logical reasoning to develop the scientific and technical abilities of the student. The participation of students will be encouraged by means of discussions on the topics taught.

Practice lessons:

Practice lessons will be aimed at the resolution of exercises and case-studies. Practice lessons are intended as a correlation between the content of theory lessons and engineering practice, in order for the student to achieve the ability to apply the acquired knowledge in the future career. The teacher will first solve some exercises and case-studies to show the students how to work on their own later.

Laboratory classes:

Two main laboratory classes will take place during the course, aimed at the understanding of working principles of measurement techniques in structural engineering. The two classes will be aimed at static and dynamic measurements, respectively. Students will take their own measurements individually or in groups. Some exercises of the student's notebook will be related with the measurements taken in laboratory classes.

Independent work:

The student shall study the contents explained in theory lessons and shall strive to solve the exercises and case-studies.

Group work:

Some parts of laboratory classes will be allowed to be done in groups of 2-4 students.

Office hours

Office hours are intended as a complement for the students to ask questions on the content of the course. Details of office hours are detailed at the beginning of this guide for each teacher.

10. Bibliography and resources

Basic bibliography:

Fraile Mora J., García Gutiérrez P., Fraile Ardanuy J. (2012). *Instrumentación aplicada a la ingeniería.* Editorial Garceta, Madrid.

Ewins D. J. (2000). *Modal Testing: theory, practice and Application*. Editorial Research Studies Press, Baldock, Hertfordshire, Reino Unido

Complementary bibliography:

Blanco, Díaz E., Oller Martínez, S. y Gil Espert, L. (2008). Análisis experimental de estructuras. Editorial: Centro Internacional de Métodos Numéricos en Ingeniería, Barcelona, España

Web resources:

Web site of the subject, virtual platform (MOODLE).

Specific equipment:

Library of the School, Laboratory of Structures.

Table 11. Time schedule

Week (see Note 1)	Theory lessons	Practice lessons	Laboratory classes (see Note 1)	Independent work	Evaluation activities	Other activities	Hours
1	Units 1 y 2 3 h			Study Units 1 y 2 4 h 15 min			7 h 15 min
2	Unit 3 2 h	Unit 3 1 h		Study Unit 3 4 h 15 min			7 h 15 min
3	Unit 4 2 h	Unit 4 1 h		Study Unit 4 4 h 15 min			7 h 15 min
4	Unit 5 y 6 2 h	Unit 5 1 h		Study Units 5 y 6 4 h 15 min			7 h 15 min
5	Units 6 1 h		Units 1 - 5 2 h	Student's notebook 5 h 15 min			8 h 15 min
6	Unit 7 2 h	Unit 7 1 h		Study Unit 7 4 h 15 min			7 h 15 min
7	Unit 8 2 h	Unit 8 1 h		Study Unit 8 4 h 15 min			7 h 15 min
8	Unit 9 2 h	Unit 9 1 h		Study Unit 9 4 h 15 min			7 h 15 min
9	Unit 9 2 h	Unit 9 1 h		Study Unit 9 4 h 15 min			7 h 15 min
10							
11	Unit 9 2 h	Unit 9 1 h		Study Unit 9 4 h 15 min			7 h 15 min

Week (see Note 1)	Theory lessons	Practice lessons	Laboratory classes (see Note 1)	Independent work	Evaluation activities	Other activities	Hours
12	Unit 10 y 11 2 h	Unit 10 y 11 1 h		Study Units 10 y 11 4 h 15 min			7 h 15 min
13	Unit 12 2 h	Unit 12 1h		Study Unit 12 4 h 15 min			7 h 15 min
14	Unit 13 2 h	Unit 13 1 h		Study Unit 13 4 h 15 min			7 h 15 min
15			Unit 14 3 h	Student's notebook 5 h 15 min			8 h 45 min
To the exam				Independent study and preparation of final exam 15 h	Final exam 3 h		12 h 30 min
Hours	**26 h**	**11 h**	**5 h**	**76 h 30 min**	**3 h**		**121 h 30 min**

NOTE **1.** Exact dates are shown in the academic calendar.