ANX-PR/CL/001-01

LEARNING GUIDE

SUBJECT

43000438 - Bridge Dynamics

DEGREE PROGRAMME

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

ACADEMIC YEAR & SEMESTER

2022/23 - Semester 2

Index

Learning guide

1. Description

1.1. Subject details

Name of the subject	43000438 - Bridge Dynamics
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 *
Diego Guillermo Manzanal Milano	Lab Mec Comput	d.manzanal@upm.es	W - 09:00 - 13:00 W - 14:00 - 16:00
Antonio Aureo Martinez Cutillas	Torre 9º	a.martinez.cutillas@upm.es	Sin horario.

Juan Carlos Garcia Orden	Lab Mec. Comput	juancarlos.garcia@upm.es	Tu - 11:00 - 13:00 W - 11:00 - 13:00 Th - 11:00 - 13:00
Jose Maria Goicolea Ruigomez	Torre 9º	jose.goicolea@upm.es	M - 08:00 - 08:15
Fco. Javier Martinez Cutillas	Torre 9º-8	francisco.martinez@upm.es	M - 15:00 - 17:30 M - 19:30 - 20:30 Tu - 15:00 - 19:00 Tu - 20:00 - 21:00
Jose Manuel Simon-Talero Muñoz	Torre 9º	jm.simon-talero@upm.es	M - 14:00 - 16:00 W - 14:00 - 16:00
Ivan Muñoz Diaz	Lab. Estr	ivan.munoz@upm.es	W - 11:00 - 14:00 Th - 11:00 - 14:00
Alfredo Camara Casado (Subject coordinator)	Torre 9a	alfredo.camara@upm.es	W - 16:00 - 19:00

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

3. Prior knowledge recommended to take the subject

3.1. Recommended (passed) subjects

- Morfología De Puentes

3.2. Other recommended learning outcomes

The subject - other recommended learning outcomes, are not defined.

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

CE11 - 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 de puentes.

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.

4.2. Learning outcomes

RA3 - Interioriza los principios de deontología profesional para actividades de I+D+i

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

RA4 - Utiliza con eficacia recursos de información y comunicación

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

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

RA25 - Conoce el formato de seguridad necesario para poder realizar comprobaciones estructurales mediante

cálculos no lineales en estructuras reales.

RA36 - Conoce y sabe aplicar los métodos de resolución de ecuaciones no lineales

RA1 - Utiliza con eficacia, autonomía y polivalencia recursos de modelización predictiva en la temática de la materia

RA29 - Asume los principios de incertidumbre y riesgo en la aplicación de los métodos y modelos de estructuras para el estudio de los puentes

RA19 - familiarizarse con la metodología científica de las disciplinas en que se apoya la asignatura

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

RA22 - Conoce las causas de no linealidad en estructuras originadas por las condiciones de sustentación y los métodos de cálculo estructural aplicables.

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

RA24 - Conoce los métodos numéricos para resolver los cálculos estructurales no lineales.

RA27 - Aplica los métodos y modelos de cálculo de estructuras para el análisis del comportamiento de los puentes y para la comprobación de su seguridad

RA31 - Asume los principios de incertidumbre y riesgo en la aplicación de los métodos y modelos de estructuras para el estudio de los puentes.

RA33 - Conoce y sabe aplicar los fenómenos no lineales en cálculo de estrcuturas

RA34 - Conoce y sabe aplicar la mecánica de medios continuos no lineal, incluyendo grandes rotaciones y deformaciones, y comportamiento no lineal de los materiales

RA35 - Conoce y sabe aplicar los modelos de elementos finitos a preoblemas estructurales y de mecánica de sólidos no lineales

RA21 - Conoce las causas de no linealidad debida al material en estructuras, sus leyes constitutivas y los métodos de cálculo estructural aplicables.

RA42 - Knowledge of the nonlinear behaviour of concrete structures based on the interpretation of the experimental results available.

RA37 - Conoce y sabe aplicar los métodos de cálculo dinámico no lineal por elementos finitos

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

* 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

The subject deepens the concepts of dynamic analysis and bridge behaviour. It presents the different methods for dynamic analysis and the models of the different types of loads with a special emphasis on their dynamic characteristics. In this course, emphasis is put on the study of service live loads, seismic loads and aero-elastic loads. Finally, a section on dampers is delivered.

5.2. Syllabus

1. Introduction to structural dynamics

   1.1. Single-degree of freedom systems. Damped movement. Resonance. Duhamel's equation.

2. Dynamics in the time domain

   2.1. Multi-degree of freedom systems. Vibration modes. Modal analysis. Damping types. Time integration. Implicit and explicit methods.

3. Dynamics in the frequency domain

   3.1. Importance of the frequency domain. Auto-correlation function. Fourier analysis. Parseval's identity, Power spectral density.

   3.2. Single- and multi-degree of freedom systems under random loads.

4. Train-induced vibrations in railway bridges

   4.1. Description of moving loads in railway bridges. Characteristic velocities. Analysis with moving loads and coupled models. Code treatment of the problem.

5. Vehicle-induced vibrations in road bridges.

   5.1. Vehicle models and pavement irregularities. Analysis methods for wind-vehicle-bridge interaction studies. Driving safety and comfort assessment.

6. Pedestrian-induced vibrations in footbridges.

   6.1. Traditional treatment of the problem. New developments following the problems with the Millenium footbridge. Models for the action of a group of pedestrians. Dallard, Setra and Nakamura model. Code specifications.

7. Seismic actions on bridges.

   7.1. Description of the seismic action. Multi-modal analysis of the seismic response. Ductility. Capacity design. Pushover method.

   7.2. Non-linear dynamic analysis. Damping. Performance-based design. Construction details in bridges.

   7.3. Soil-structure interaction. Seismic effects on abutments. Mononobe-Okabe method.

8. Wind effects on bridges.

   8.1. Definition of wind actions in normative. Aero-elastic effects. Torsional divergence. Vortex-shedding. Galloping. Wake galloping. Flutter. Buffeting.

9. Damping devices.

   9.1. Active, semi-active and passive devices. Tuned mass dampers. Viscous shock absorbers

   9.2. Modified neoprene devices. Yielding metallic dampers. Shock transmission units. Design of auxiliary damping systems for the control of bridges. Application examples

6. Schedule

6.1. Subject schedule*

Week	Classroom activities	Laboratory activities	Distant / On-line	Assessment activities
1	**Unit 1** Duration: 02:30 Lecture **Unit 1** Duration: 01:15 Problem-solving class			**Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.** Individual work Continuous assessment Not Presential Duration: 00:30
2	**Unit 2** Duration: 02:30 Lecture **Unit 2** Duration: 01:15 Problem-solving class			**Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.** Individual work Continuous assessment Not Presential Duration: 00:30
3	**Unit 3** Duration: 02:30 Lecture **Unit 3** Duration: 01:15 Problem-solving class			**Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.** Individual work Continuous assessment Not Presential Duration: 00:30
4	**Unit 4** Duration: 02:30 Lecture **Unit 4** Duration: 00:45 Problem-solving class			**Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.** Individual work Continuous assessment Not Presential Duration: 00:30
5	**Unit 5** Duration: 02:30 Lecture **Unit 5** Duration: 01:15 Problem-solving class			**Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.** Individual work Continuous assessment Not Presential Duration: 00:30
6	**Unit 6** Duration: 02:15 Lecture **Unit 6** Duration: 01:15 Problem-solving class			**Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.** Individual work Continuous assessment Not Presential Duration: 00:30

7	**Unit 7** Duration: 02:30 Lecture **Unit 7** Duration: 00:45 Problem-solving class			**Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.** Individual work Continuous assessment Not Presential Duration: 00:30
8	**Unit 7** Duration: 02:30 Lecture **Tema 7** Duration: 01:15 Problem-solving class			**Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.** Individual work Continuous assessment Not Presential Duration: 00:30
9	**Unit 7** Duration: 02:30 Lecture **Unit 7** Duration: 01:15 Problem-solving class			**Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.** Individual work Continuous assessment Not Presential Duration: 00:30
10	**Unit 7** Duration: 02:30 Lecture **Unit 7** Duration: 01:15 Problem-solving class			**Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.** Individual work Continuous assessment Not Presential Duration: 00:30
11	**Unit 8** Duration: 02:30 Lecture **Unit 8** Duration: 00:45 Problem-solving class			**Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.** Individual work Continuous assessment Not Presential Duration: 00:30
12	**Unit 8** Duration: 02:30 Lecture **Unit 8** Duration: 01:15 Problem-solving class			
13	**Unit 8** Duration: 02:30 Lecture **Unit 8** Duration: 01:15 Problem-solving class			**Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.** Individual work Continuous assessment Not Presential Duration: 00:30

14	**Unit 8** Duration: 02:30 Lecture **Unit 8** Duration: 00:45 Problem-solving class			**Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.** Individual work Continuous assessment Not Presential Duration: 00:30
15	**Unit 9** Duration: 02:30 Lecture **Unit 9** Duration: 00:45 Problem-solving class			
16				**Final exam** Written test Final examination Not Presential Duration: 03:00
17				

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
1	Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.	Individual work	No Presential	00:30	5%	5 / 10	CG1 CG4 CG5 CB6 CB9 CB10 CE11
2	Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.	Individual work	No Presential	00:30	5%	5 / 10	CE11
3	Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.	Individual work	No Presential	00:30	5%	5 / 10	CG1 CG4 CG5 CB6 CB9 CB10 CE11
4	Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.	Individual work	No Presential	00:30	5%	5 / 10	CE11
5	Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.	Individual work	No Presential	00:30	5%	5 / 10	CE11 CG1 CG4 CG5 CB6 CB9 CB10
6	Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.	Individual work	No Presential	00:30	5%	5 / 10	CE11

7	Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.	Individual work	No Presential	00:30	5%	5 / 10	CG1 CG4 CG5 CB6 CB9 CB10 CE11
8	Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.	Individual work	No Presential	00:30	5%	5 / 10	CE11
9	Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.	Individual work	No Presential	00:30	5%	5 / 10	CG1 CG4 CG5 CB6 CB9 CB10 CE11
10	Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.	Individual work	No Presential	00:30	5%	5 / 10	CE11
11	Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.	Individual work	No Presential	00:30	5%	5 / 10	CG1 CG4 CG5 CB6 CB9 CB10 CE11
13	Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.	Individual work	No Presential	00:30	5%	5 / 10	CE11
14	Class exercise: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home.	Individual work	No Presential	00:30	10%	5 / 10	CG1 CG4 CG5 CB6 CB9 CB10 CE11

7.1.2. Global examination

Week	Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills

16	Final exam	Written test	No Presential	03:00	100%	5 / 10	CG1 CG4 CG5 CB6 CB9 CB10 CE11

7.1.3. Referred (re-sit) examination

Description	Modality	Type	Duration	Weight	Minimum grade	Evaluated skills
Examen extraorinario	Written test	Face-to-face	03:00	100%	5 / 10	CG4 CG5 CB6 CB9 CB10 CE11

7.2. Assessment criteria

Assessment through continuous evaluation

PE1. Class exercises 70%

Description: It consists of a series of practical exercises, each of which will begin in the classroom and the student must finish at home. They will be personalized exercises in a way that favours the individual work of the student.

Criteria of qualification: Each exercise will be valued from 0 to 10. The qualification of this evaluation test will be the weighted average of all the exercises carried out during the course, according to the difficulty of each of them.

Moment and place: The exercises will be set weekly. The lecturer will guide the students to solve the problems at the end of each lesson, and they will finish them working on their own after the session and before the next exercise is set, promoting this way continuous work and feedback.

PE2. Attendance control 30%

Description: Class attendance is monitored.

Qualification criteria: The rating is proportional to the number of lessons that the students attends.

Final score of the subject through continuous assessment

The final grade will be the weighted average of the different controls according to the weights specified above.

To pass the subject, the final grade must be equal to or greater than 5.

If the student of continuous evaluation does not pass the subject in the ordinary call they must go to the extraordinary assessment. The format of this type of assessment is indicated in the "assessment through final test only".

Assessment through final test only

Description. The final exam will consist of exercises with a level similar to the ones proposed during the course and focusing on at least two of the thematic blocks (units) of the course.

Qualification criteria. Each examination exercise is valued from 0 to 10. The exam grade will be the arithmetic average of the grade obtained in the exercises that form the exam as long as the grades corresponding to each of them are above or equal 3.5.

Moment and place: To be determined by the Head of Studies in due course.

8. Teaching resources

8.1. Teaching resources for the subject

Name	Type	Notes
Clough R.W. & Penzien J. (1993), Dynamics of Structures, McGraw-Hill	Bibliography	Further reading
Chopra A.K. (2011), Dynamics of Structures, Prentice Hall	Bibliography	Basic
Humar J. (2012), Dynamics of Structures, CRC Press	Bibliography	Further reading
Bachman H. (1995), Vibration problems in structures, Birkhäuser	Bibliography	Further reading

Fryba L. (1999), Vibration of solids and structures under moving loads, Thomas Telford	Bibliography	Basic
O'Connor & Shaw P.A. (2000), Bridge Loads, Spon Press	Bibliography	Basic
fib (2005), Guidelines for the design of footbridges, fib Bulletin nº 32	Bibliography	Basic
Priestley N., Seible F. & Calvi G.M. (1996), Seismic Design and Retrofit of Bridges, Wiley	Bibliography	Basic
Davidovici V.E. (1992), Earthquake Engineering and Structural Dynamics, Ouest Editions	Bibliography	Further reading
Chen W.F. & Duan L. (2003), Bridge Engineering: Seismic Design, CRC Press	Bibliography	Further reading
Kappos A.J., Saiidi M.S., Aydinoglu M.N. & Isakovic T. (2012), Seismic Design and Assessment of Bridges, Springer	Bibliography	Further reading
Simiu E. & Scanlan R.H. (1996), Wind effects on Structures, John Wiley & Sons	Bibliography	Basic
Dyrbye C. & Hansen S.O. (1996), Wind loads on structures, Wiley	Bibliography	Further reading
T.T. Soong and G.F. Dargush. Passive energy dissipation systems in structural engineering. John Wiley and Sons, Chichester (UK), 1997.	Bibliography	Basic
Strommen E. (2006), Theory of Bridge Aerodynamics, Springer	Bibliography	Basic
Área virtual de la ETSICCP. Área virtual (MOODLE)	Web resource	

Biblioteca del departamento de Mecánica de Medios Continuos y Teoría de Estructuras.	Equipment	

9. Other information

9.1. Other information about the subject

Theory lessons:

The lecturer will explain the concepts necessary to understand the concepts of the course in order for the student to achieve the expected indicators. The lecturer 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 being 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 students to achieve the ability to apply the acquired knowledge in their future careers. The lecturer will first solve some exercises and case-studies to show the students how to work independently to solve the proposed class exercises.

Laboratory classes:

Some exercises will require using a computer to solve numerical models on bridge dynamics. The lecturer will provide support to the students to perform this analysis on their own computers or using the University ones.

Independent work:

The student shall study the contents explained in theory lessons and shall try to solve the exercises and case-studies, asking relevant questions to the lecturers if they need support.

Group work:

There are no group works planned in this module.

Office hours

Office hours are intended as a complement for the students to ask questions about the content of the course. Details of office hours are included at the beginning of this guide for each academic involved in the course.