

Design, Analysis and Construction of Bridges

1. General overview

UPM Code	Credits	Type	Specialization	Language
43000388	4,5	Optional	Structures, Geotechnics, Construction and Materials	English
Name in Spanish	Proyecto, cálculo y construcción de puentes			
Subject	Option of Structures, Geotechnics, Construction and Materials			
Department	Continuum Mechanics and Structures Theory			
Web page	http://moodle.upm.es/titulaciones/oficiales			
Semester	Fourth semester			
Formación predoctoral	Asignatura válida como créditos formativos de admisión al Programa de Doctorado D6 <i>Doctorado em Ingeniería de Estructuras, Cimentaciones y Materiales</i> , según la línea de investigación de la tesis doctoral			

2. Teaching staff

Name	Evaluation jury	Group	Office hours	Place	E-mail address
Miguel Ángel Astiz Suárez	Chair	All	Tue, 10:00-14:00 Thur, 17:00-19:00	Tower 9 th	miguel.a.astiz@upm.es
Miguel Ángel Gil Ginés	Member	All	Fri, 16:00-19:00	Tower 9 th	angel.gil@upm.es

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

3. Previous knowledge

Courses that must be taken in advance:

Bridge morphology

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.
CM45	Understanding and assumption of the uncertainty, risk and opportunity principles in the application of civil engineering models and methods.
CT8	Ability to design, analyse and understand relevant experiments in civil engineering.

5. Student outcomes

Code	Learning results	Competences linked
SO1	Lays out a bridge project over the traverse data, functionality, topography and geotechnics basis available.	CGP11, CM45
SO2	Applies the structural analysis methods and models for the bridge 2raducci analysis and for its safety test.	CM45, CT8
SO3	Lays out the bridge construction method.	CGP11, CM45
SO4	Assumes the uncertainty and risk principles in the application of the structures methods and models for the bridge studies.	CM45

6. Achievement indicators

Code	Basic	Indicators of achievement	SO linked
IL1	Yes	Knows the different bridge types, their behaviour and their scope.	SO1
IL2	Yes	Lays out the different possible alternatives in a conventional, medium span or large span bridge project.	SO1, SO3, SO4
IL3	Yes	Defines the approximate dimensions of the different bridge elements in a conventional, medium span or large span bridge.	SO1, SO4
IL4	Yes	Correctly studies the bridge superstructure calculus in a conventional, medium span or large span bridge.	SO2, SO4
IL5	No	Correctly lays out a conventional, medium span or large span bridge construction.	SO1, SO3, SO4
IL6	No	Knows the way to approach the study of the effects over the bridge of some extraordinary actions.	SO2, SO4
IL7	Yes	Knows the methodology to establish a bridge inspection, conservation and maintenance program.	SO1, SO4

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
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7.1. Evaluation through "continuous assessment"

EM1. Class exercises **10%**

Description: Consists on a series of theoretical or practical questions, each of which will be done in the classroom or through the Virtual Classroom (Moodle). It will also be taken into account the class participation.

Evaluation criteria: Each exercise will be ranked from 0 to 10 points. The final score of this part will be the mean average of all the exercises done during the course, according to the difficulty of each one.

Place and period: The questions will be proposed, without notifying, during the class hours. The exercise will be done in the classroom. The questions proposed through the Virtual Classroom (Moodle) will be done according the conditions and dates that will be announced during the course.

EM2. Control at the end of thematic units **20%**

Description: Consists of the resolution a series of theoretical or practical exercises done during the class hours.

Evaluation criteria: Each exercise will be ranked from 0 to 10. The final evaluation of these tests will be the arithmetic mean of all exercises done during the course.

Code, name of evaluation methods, brief description of evaluation methods, criteria, place and period of evaluation	Weight
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Place and period: In class, in predetermined dates, once the classes related to the thematic unit are finished.

EM3. Midterm exam **35%**

Description: Consists of an exam that has several theoretical and practical questions, related to the units treated during the classes until the exam date. The approximate duration of the exam will be 1 hour and 30 minutes.

Evaluation criteria: The paper will be ranked from 0 to 10 doing the arithmetic mean of the score of each exercise.

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

EM4. Final exam **35% or 70%**

Description: It will consist of two parts, each of them will last 1 hour and 30 minutes. The first one will have several theoretical and practical questions related to the lessons of the midterm exam. It is not obligatory for the students who have reached a score of 4 or higher in the midterm exam to be examined of this part although they can be examined if they want to reach a higher score. For the students who do the midterm exam and the first part of the final exam it will also be taken into account the best of the scores reached in the two exams.

The second part, which will have to be done by all the students, has several theoretical and practical questions, related to the units not included in the midterm exam. All the students have to do this part.

Evaluation criteria: Each exercise will be ranked from 0 to 10. The final score of the exam will be the arithmetic mean of the scores obtained in the exercises. For the students who do the two parts, the weight of the final exam will be the 70% and for those who only do the second part, it will be the 35%.

Place and period: To be determined by the Head of Studies. For organization reasons, first it will be done the second part of the subject (obligatory for all the students). Once this is done, the students who have to or want to do the first part of the subject will do the first part.

Result of the evaluation through “continuous assessment”

The final score will be the highest of the following:

- For the students who pass the midterm exam: PE1 (10%), PE2 (20%), PE3 (35%) and PE4 (35%), provided that the PE3 and PE4 marks are not lower than 3.5.
- For the students who do the complete final exam: PE1 (10%), PE2 (20%), and PE4 (70%), provided that the PE4 mark is not lower than 3.5.
- For all the students, the mark which would have obtained by the evaluation through “final exam only” described below. For the students that have not done the first part of the final exam, it will be used to rank this part their score in the midterm 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) which will have the same format as the evaluation through “final exam only”.

7.2. Evaluation through “final exam only”

Description: Consists of the same final exam as the one that will do the students who choose the “continuous assessment” evaluation.

Evaluation criteria: Each of the exercises will be ranked from 0 to 10 points. The final score will be the arithmetic mean of the scores obtained in each exercise provided that the marks obtained in the first and the second parts are not lower than 3.5.

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

Code, name of evaluation methods, brief description of evaluation methods, criteria, place and period of evaluation	Weight
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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
Unit 1. Introduction to non conventional, medium span or large span bridges Determinants that led to plan a non conventional bridge. Bridge typology. Examples.	A11
Unit 2. The caisson section straight bridge Transverse and longitudinal morphology. Resistant behaviour: longitudinal bending, cross bending, torsion, non uniform torsion, distortion, application of numerical methods, bridge modelling. Construction: movable falseworks, placement beams, consecutive cantilevers, precast segments.	A11, A12, A13, A14, A15
Unit 3. The skew bridge Morphology. Linkages. Resistant behaviour: beam bridge, slab bridge, caisson section bridge. Modelling. Prestressing plotting. Applications.	A11, A12, A13, A14
Unit 4. The curve bridge Morphology. Linkages. Resistant behaviour: beam bridge, slab bridge, caisson section bridge. Modelling. Prestressing plotting. Applications.	A11, A12, A13, A14
Unit 5. The rigid frame bridge. Morphology. Linkages. Resistant behaviour depending on the terrain and linkages. Prestressing plotting. Support types. Construction. Applications.	A11, A12, A13, A14, A15
Unit 6. The railroad bridge Morphology. Special features of the hi-speed railroad bridges. Specific actions on railroad bridges. Spanish and European regulation. Serviceability conditions. Location of expansion joints in the bridge and on the road. Introduction to dynamic effects.	A11, A12, A13, A14
Unit 7. Pushed bridges. Definition. Conditions of the application of the pushing procedure for the bridge construction. Process description. Process analysis. Modelling. Implication of the construction procedure on the definition of prestressing. Applications.	A11
Unit 8. Arch bridges. Morphology. Linkages. Resistant behaviour: deck bridge, through bridge, tympanum bridge, network bridge. Arch construction. Applications.	A11, A12, A13, A14, A15
Unit 9. Cable-stayed bridges. Longitudinal morphology. Cross morphology. Towers. Cable properties. Cable-stayed bridge behaviour against vertical and horizontal actions. Calculation of cable-stayed bridges. Definition of reference state. Modelling. Construction process: cantilever method, over provisional supports. Vibration problems. Applications.	A11, A12, A13, A14, A15

Units, sections and descriptors	Achievement indicators linked
Unit 10. Extradosed bridges. Longitudinal morphology. Cross morphology. Towers. Cable properties. Extradosed bridge behaviour against vertical and horizontal actions. Calculation of extradosed bridges. Definition of reference state. Construction process	AI1, AI2, AI3, AI4, AI5
Unit 11. Extraordinary actions. Scouring: description, research, protection design. Ship collision: description, actions during the collision, calculation, protection against the ship collision.	AI2, AI6
Unit 12. Inspection and maintenance. Bridge management. Periodic inspection policy. Maintenance programs. Bridge rehabilitation.	AI7

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:

No laboratory classes will be conducted on this subject

Independent work:

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

Group work:

There are not any specific group works.

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:

- Hewson N.R. (2003), *Prestressed Concrete Bridges*, Thomas Telford
 Manterola J. (2006), *Puentes: Apuntes para su Diseño, Cálculo y Construcción*, Colegio de Ingenieros de Caminos, Canales y Puertos
 Menn C.(1986), *Prestressed Concrete Bridges*, BirkHäuser Verlag
 Walther R., Houriet B., Isler W., Moia P. & Klein J.F. (1999), *Cable Stayed Bridges*, Thomas Telford

Complementary bibliography:

- Benaim R. (2008), *The Design of Prestressed Concrete Bridges*, Taylor & Francis
- Calgaro J.A. (1988), *Projet et Construction des Ponts: Analyse Structurale des Tabliers de Ponts*, Presses de l'École Nationale des Ponts et Chaussées
- Leonhardt F. (1982), *Bridges*, Deustche Verlags-Anstalt
- Liebenberg A.C. (1992), *Concrete Bridges: Design and Construction*, Longman Scientific and Technical
- Monleón S. (1997), *Ingeniería de Puentes: Análisis Estructural*, Universidad Politécnica de Valencia
- Svensson H. (2012), *Cable Stayed Bridges: 40 Years of Experience Worldwide*, Wiley

Web resources:

Virtual platform (MOODLE). Virtual platform of the ETSICCP

Specific equipment:

Library of the department of continuum mechanics and structure theory.

Table 11. Time schedule

Week (see Note 1)	Theory lessons	Practice lessons	Laboratory classes	Independent work	Evaluation activities	Other activities	Hours
1	Unit 1 3 h			Study Unit 1 4 h 45 min			7 h 45 min
2	Unit 2 2 h	Unit 2 1 h		Study Unit 2 4 h 45 min			7 h 45 min
3	Unit 2 2 h	Unit 2 1 h		Study Unit 2 4 h 45 min			7 h 45 min
4	Unit 2 2 h	Unit 2 1 h		Study Unit 2 and preparing for the control 5 h 15 min	Control 30 min		8 h 45 min
5	Unit 3 2 h	Unit 3 1 h		Study Unit 3 4 h 45 min			7 h 45 min
6	Unit 4 2 h	Unit 4 1 h		Study Unit 4 4 h 45 min			7 h 45 min
7	Unit 5 2 h	Unit 5 1 h		Study Unit 5 and preparing for the control 5 h 15 min	Control 30 min		8 h 45 min
8	Unit 6 2 h	Unit 6 1 h		Study Unit 6 and preparing for the midterm exam 5 h 15 min	Midterm exam 1 h 30 min		9 h 45 min
9							
10	Unit 7 2 h	Unit 7 1 h		Study Unit 7 4 h 45 min			7 h 45 min

Week (see Note 1)	Theory lessons	Practice lessons	Laboratory classes	Independent work	Evaluation activities	Other activities	Hours
11	Unit 8 2 h	Unit 8 1 h		Study Unit 8 and preparing for the control 5 h 15 min	Control 30 min		8 h 45 min
12	Unit 9 2 h	Unit 9 1 h		Study Unit 9 4 h 45 min			7 h 45 min
13	Unit 10 2 h	Unit 10 1 h		Study Unit 10 and preparing for the control 5 h 15 min	Control 30 min		8 h 45 min
14	Unit 11 2 h	Unit 11 1 h		Study Unit 11 4 h 45 min			7 h 45 min
15	Unit 12 2 h	Unit 12 1 h		Study Unit 12 4 h 45 min			7 h 45 min
To the exam				Independent study and preparation of the final exam 5 h	Final exam 4 h		9 h
Hours	29 h	13 h		72 h	7 h 30 min		121 h 30 min

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

