STRUCTURAL TYPES AND CALCULATION 1

Bachelor in Architectural Studies BAS SEP-2023 STC1-AS.2.S.A

Area Architecture and Design
Number of sessions: 40
Academic year: 23-24
Degree course: SECOND
Number of credits: 6.0
Semester: 2º
Category: COMPULSORY
Language: English

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Summmary

Professional background combining strong technical knowledge as researcher and structural engineer of bridges and buildings with management experience in a higher education multinational company with important academic and business responsibilities.

Academic Background

- 1992: MSc Civil Engineer, Technical University of Madrid
- 1996 - 2001: Doctoral studies at the Swiss Federal Institute of Technology, Lausanne (ICOM-EPFL). PhD thesis: “Concrete Cracking in the Deck Slabs of Steel-Concrete Composite Bridges”.
- 2018: General Management Programme, PDG – IESE Business School, Universidad de Navarra, Madrid.

Academic experience

- 2007-2009: Associate Professor at the Building Structures Department at the School of Architecture at Universidad Politécnica de Madrid: Statics, Prestressed Concrete, Steel Structures
- 2009-2017: Director of the School of Architecture, Engineering and Design at Universidad Europea de Madrid
- 2017: Chancellor at Universidad Europea de Madrid
- 2018-: Adjunct Professor IE Universidad
- 2022-: Associate Professor at the Building Structures Department at the School of Architecture at Universidad Politécnica de Madrid: Structural Design and Capstone project

Corporate experience

- 1992: Structural Engineer, Arup, London, www.arup.com
- 1992 - 1996: Structural Engineer, Esteyco, Madrid, www.esteyco.es

- 2001 - 2009: Technical Director of MC2 Estudio de Ingeniería: SyV and Espacio Towers, Arganzuela Footbridge (Dominique Perrault), Water Tower in International Exhibition Zaragoza 2008, Teatros del Canal (Juan Navarro Baldeweg), Spanish Pavilion in Shanghai Universal Exhibition 2009 (Benedetta Tagliabue). www.mc2.es
- 2018-2022: Director of the Building Structures Division at Fhecor, Ingenieros Consultores, www.fhecor.es
- 2022-: Madrid Office Director at BIS structures, www.bisstructures.com
  www.linkedin.com/in/miguel-gomez-navarro

Office Hours

Office hours will be on request. Please contact at:

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SUBJECT DESCRIPTION

The course aims to familiarize students with the basic instruments for the design of building structures: structural types, design and analytical processes, methods, formulas, materials, optimization suggestions, constructive solutions…

Making good architecture is, among other things, designing correct and useful structures that are integrated into the global project. It is useful that structural design is involved in the global design from the very beginning, intending to find the appropriate structural type adapted to the needs of the project. Structural design must always be guided by common sense and the understanding of its basic principles in the same way as it is, for example, the organization of space.

Most people have a broad intuitive sense of structures from everyday observations of the world around us. But the designer also needs an elementary understanding of the numerical methods of structural quantification to complement this intuition. In order to bring together all the diverse requirements and incorporate these into an aesthetic and viable design, the architect needs to have a feel for the relative importance of variables like span, depth, thickness, slenderness, angles, loads, stiffness, material properties, and so on.

This course is intended to give architectural students an introduction to such basic principles and quantitative methods. It will combine thus theoretical concepts introduced and simple analytical techniques to quantify the concepts learned earlier. The aim will be to discuss structural methods in such a way that it gives the architect-to-be an appreciation of the role that structures can play in influencing architectural design. Many of the great architectural works have come about through a close dialogue between architect and structural designer, and for this dialogue to flourish the architect must not only understand the structural issues in intuitive terms but also needs to be able to speak the language of the structural designer.

It is not the intention of the course to make students proficient in complex analytical techniques; it will remain focused on ‘manual methods’ of calculation which can be the most effective way in demonstrating basic formulae that describe structural behaviour. Optimising a design normally involves decisions influenced by structure at the early concept stages of the project, and at this stage most calculations should be able to be done manually to choose the way in which the parameters can be varied in the correct way.

Throughout the course there will be references to the analysis of existing buildings, and exercises will be proposed regularly to ensure familiarity with the analytical techniques presented. By the end of the course the student should have an elementary understanding of the design process and be capable of applying all the analytical steps necessary for the design of simple beam elements.

The course is organized into four units. The units are not strictly sequential and part of their content is repeated, being exposed and developed in a deeper and more detailed manner each time. The four sections are:

- Introduction to Structural Design
- Loads and materials
- Structural Analysis (I)
- Structural Analysis (II)

In the first unit all the stages and processes involved in the design of a structure are described. The student will learn, in general terms, the basic typologies and the role of structural design in the global design of a building.

The second unit will focus on the loads that must be resisted by a structured transferring them to the foundations. The most important structural materials are analysed and compared in terms of their main properties.

The main tools used for the analysis of structural systems will be studied in units 3 and 4. Verifications, codes and simpleo or computer models will be presented in a simple way enabling their future practical use. These units include the analysis of the internal forces systems that a structure must develop to accommodate the external forces acting on it and transfer them to the foundations. The sessions focus on direct stresses and deflections due to axial forces and bending moments. Shear stresses due to shear forces and torsional moments, as well as an introduction to special issues as instability or bracing will be studied in the final sessions.

Several case studies will be analysed during the course to reinforce the comprehension of structural behaviour. These case studies will be complemented by the study of a project developed by the student in which a proposal for the integration of the structure will be developed along the course.

Finally, a visit to a materials laboratory will be carried out in order to apprehend the real behaviour of different structural materials and elements by means of tests. A construction site visit will be carried out depending on availability, incluiding a previous analysis of the buildings to be visited.

LEARNING OBJECTIVES

Per Ministerial Decree EDU/2075/2010, 29 of July; and the official accreditation request for the Bachelor in Architectural Studies, July 2015; see BOCYL, 14 March 2018: p. 10477-10481

2.1. BASIC AND GENERAL OBJECTIVES

- CB1: Students have demonstrated knowledge and an understanding of a given area of study, building upon the foundation of secondary education, supported by advanced texts, and including aspects that engage the latest advances in their area of study.
- CB2: Students know how to apply their knowledge professionally to their work or vocation and possess the competencies that are often demonstrated through elaboration and defence of arguments and the resolution of problems within their area of study.
- CB3: Students can gather and interpret relevant facts (usually within their area of study) in order to make judgments that include reflection on relevant social, scientific, and ethical topics.
- CB4: Students can transmit information, ideas, problems, and solutions to both specialized and non-specialized audiences.
- CB5: Students have developed the necessary learning skills to continue their studies with a

high degree of autonomy.

- CG4: An understanding of the fundamental issues in structural design, construction, and engineering as related to building projects, as well as the techniques used to address these issues.
- CG5: Knowledge of the issues related to building physics, technologies, and programmatic uses, in order to create buildings that provide internal comfort and protection from the elements.
- CG6: Knowledge of the industries, organizations, regulations, and procedures needed in order to transform projects into buildings, and to integrate drawings into the planning process.

2.2. SPECIFIC COMPETENCIES (Per the Ministerial Decree EDU/2075/2010, 29 of July)

PREPARATORY MODULE (CE1-11)

- CE7: Adequate knowledge of the fundamental principles of mechanics, statics, mass point geometry and vector and tensor fields, as applied to architecture and urbanism.

TECHNICAL MODULE (CE 12-33)

- CE12: Ability to devise, calculate, design and implement foundation solutions, and to integrate them into buildings and urban assemblies (W).
- CE13: Ability to apply technical and constructive codes and regulations.
- CE14: Ability to preserve building structures, foundations and public works.
- CE17: Capacity to develop, calculate, design, and execute building structures, and to integrate them into buildings and urban complexes (W).
- CE19: Capacity to develop, calculate, design, and execute enclosure systems, roofs/coverings, and other structural work, and to integrate them into buildings and urban complexes (W).
- CE24: Adequate knowledge of the mechanics of solids, continuous media and soil, as well as the plastic, elastic, and resistance qualities of heavy building materials.
- CE25: Adequate knowledge of conventional construction systems and their pathology.
- CE26: Adequate knowledge of the physical and chemical characteristics of the production process, the pathology, and use of building materials.
- CE27: Adequate knowledge of industrial construction systems. tic, elastic, and resistance qualities of heavy building materials.

2.3. TRANSVERSE COMPETENCIES OF THE UNIVERSITY

- CT2: Ability to exercise professional behaviour in accordance with constitutional principles and ethical values of the respective profession.
- CT4: Use disciplinary knowledge to analyse and evaluate current situations.
- CT5: Integrate oneself into interdisciplinary and multicultural teams to achieve common goals in a context of diversity.

TEACHING METHODOLOGY

IE University teaching method is defined by its collaborative, active, and applied nature. Students actively participate in the whole process to build their knowledge and sharpen their skills. Professor's main role is to lead and guide students to achieve the learning objectives of the course. This is done by engaging in a diverse range of teaching techniques and different types of learning activities such as the following.

In the lectured classes the theory will be presented with the help of visual aids to help explain structural concepts, and will be further illustrated by means of case studies, worked examples and graphical representation.

Students will be expected to prepare the exercises set in previous classes, search for relevant information to supplement lecture notes, prepare for workshops and even maybe take part in a group activity outside of lecture hours. The hours expected to be dedicated to these activities are set out in the table below, and all this time will be orientated towards achieving a good understanding of the material explained in the content description.

Basic structural concepts are expected to be laid to prepare the student for future steps in his/her learning process. Special attention will be paid to case studies since they are a powerful tool to strengthen basic concepts and structural types. Observation of structural behaviour on a structural laboratory is also a complementary tool that reinforces the understanding of materials and structural types behaviour. Finally, a case study will be complemented by a visit to its construction site in which structural types could be observed.

This course will involve the following teaching methods:

AF1: Workshops and Laboratories: work sessions with individual and group learning, with a practical character, oriented toward the resolution of problems, and of controlled experiments, with review, debate, and personalized tutorials. Workshops may use the digital platform, while laboratories will be held in spaces equipped for that purpose.

AF2: Lectures: explanations of theoretical content, led by the professor. Classes as guide for students' autonomous work, with presentations, answers to questions, and the posing of relevant questions through the use of texts and practical cases as illustrations. These classes may use the digital platform.

AF5: Presentation of Work: oral, public exhibition of student work. Occasionally these may be held via the digital platform.

AF9: Individual Study: prior or posterior study of the corresponding topic, according to the proposed plan of study, in order to take better advantage of the in-class explanations. Review of class notes and of class topics, with study of the bibliography as well as reflections on texts proposed by the instructor, with the possible addition of texts suggested by the student. Includes readings from the recommended bibliography as well as complementary readings at the students' discretion.

A10: Preparation of Projects: Preparation of architectural projects, drawings, models, brief texts, analysis and critiques of texts read in class, as well the development of essays on a topic proposed by the professor and chosen by the student, with the supervision of a professor, in relation to the material developed in class, and the study of assigned texts, with the aim of integrating theoretical knowledge with reality. Includes research.

Learning Activity	**Weighting**	**Estimated time a student should dedicate to prepare for and participate in**
Lectures	23.33 %	35.0 hours
Discussions	10.0 %	15.0 hours
Exercises in class, Asynchronous sessions, Field Work	6.67 %	10.0 hours
Group work	13.33 %	20.0 hours
Individual studying	46.67 %	70.0 hours
TOTAL	100.0 %	150.0 hours

PROGRAM

UNIT 1: INTRODUCTION TO STRUCTURAL DESIGN

SESSIONS 1 - 2 (LIVE IN-PERSON)

Introduction to Building Structures. The role of structural design in architecture.

SESSIONS 3 - 4 (LIVE IN-PERSON)

Introduction to structural typologies and basic concepts of structural design. 2D elements: Columns, cables, beams, frames, trusses. 3D elements: slabs, spatial structures.

Recap of Applied Phisycs 1: main concepts of structural analysis, simple beams, equilibrium, internal forces

SESSIONS 5 - 6 (LIVE IN-PERSON)

Introduction to structural typologies and basic concepts of structural design. 2D elements: Columns, cables, beams, frames, trusses. 3D elements: slabs, spatial structures.

Case study (I)

A real building will be analysed in order to study the main features of its structural system and understand the relations with the global architectural needs. Special attention will be paid to the support distribution, the structural challenges and the construction procedure. The general concepts about structural typologies, loads, and material behaviour will be applied, enabling students to reinforce their general structural knowledge and apply it to their own Design Studio case study.

A comparison between groups of buildings with similar functions but different structural approaches could also be carried out: petrol stations, congress halls, industrial facilities, etc.

SESSIONS 7 - 8 (LIVE IN-PERSON)

Presentation of the group exercise: Structural design & construction procedure of a singular structure. Presentation of the individual exercise: Structural concepts for your design studio project

Case study (II)

A real building will be analysed in order to study the main features of its structural system and understand the relations with the global architectural needs. Special attention will be paid to the support distribution, the structural challenges and the construction procedure. The general concepts about structural typologies, loads, and material behaviour will be applied, enabling students to reinforce their general structural knowledge and apply it to their own Design Studio case study.

A comparison between groups of buildings with similar functions but different structural approaches could also be carried out: petrol stations, congress halls, industrial facilities, etc.

UNIT 2: LOADS AND MATERIALS

SESSIONS 9 - 10 (LIVE IN-PERSON)

Loads acting on structures: gravity, wind, earthquakes, thermal effects. Permanent, variable and accidental loads. Combination of loads. Fire considerations.

SESSIONS 11 - 12 (LIVE IN-PERSON)

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SESSIONS 13 - 14 (LIVE IN-PERSON)

Structural materials: steel (structural, reinforcing, prestressing), concrete, aluminium, wood, stone, glass. Basic properties (elastic and plastic resistance, rigidity, cost)

SESSIONS 15 - 16 (LIVE IN-PERSON)

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SESSIONS 17 - 18 (LIVE IN-PERSON)

Test 1

Case study (III)

A real building will be analysed in order to study the main features of its structural system and understand the relations with the global architectural needs. Special attention will be paid to the support distribution, the structural challenges and the construction procedure. The general concepts about structural typologies, loads, and material behaviour will be applied, enabling students to reinforce their general structural knowledge and apply it to their own Design Studio case study.

A comparison between groups of buildings with similar functions but different structural approaches could also be carried out: petrol stations, congress halls, industrial facilities, etc.

UNIT 3: STRUCTURAL ANALYSIS (I)

SESSIONS 19 - 20 (LIVE IN-PERSON)

Verifications required. Serviceability and ultimate limit state analyses. Loads transmission. Foundation analysis. Durability. Codes and regulations. Safety formats

Axial forces. Compression and tension. Columns, cables, trusses. Stresses, deformations. RC columns. Thermal effects and expansion joints.

SESSIONS 21 - 22 (LIVE IN-PERSON)

Axial forces. Compression and tension. Columns, cables, trusses. Stresses, deformations. RC columns. Thermal effects and expansion joints.

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SESSIONS 23 - 24 (LIVE IN-PERSON)

Bending moment. Diagrams in simply supported and continuous steel beams: stress limits, bending resistance, influence of cross-sectional shape, sectional properties. Deflection controls in steel beams.

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Bending moment. Diagrams in simply supported and continuous steel beams: stress limits, bending resistance, influence of cross-sectional shape, sectional properties. Deflection controls in steel beams.

SESSIONS 27 - 28 (LIVE IN-PERSON)

Visit to a structural laboratory. Observation of material and structural behaviour. Testing and instrumentation of structures.

SESSIONS 29 - 30 (LIVE IN-PERSON)

Test 2

Case study (IV): Visit to a construction site or finished building. - Preparation

SESSIONS 31 - 32 (LIVE IN-PERSON)

Case study (IV) - Visit to a construction site or finished building.

UNIT 4: STRUCTURAL ANALYSIS (II)

SESSIONS 33 - 34 (LIVE IN-PERSON)

Reinforced concrete beams: basic concepts and reinforcement distribution. Composite beams.

Instability of elements in compression: buckling. Bracing elements to resist horizontal loads.

SESSIONS 35 - 36 (LIVE IN-PERSON)

Shear forces distribution in simply supported beams. Shear stresses in steel sections. Webs and flanges. Shear reinforcement in reinforced concrete elements.

Torsional forces. Global equilibrium and deformations. Stiffness. Open and close sections

SESSIONS 37 - 38 (LIVE IN-PERSON)

Presentation of group exercises

SESSIONS 39 - 40 (LIVE IN-PERSON)

Global test

EVALUATION CRITERIA

(Per Ministerial Decree EDU/2075/2010, 29 of July; and the official accreditation request for the Bachelor in Architectural Studies, July 2015; see BOCYL, 14 March 2018: p. 10477-10481)

This course will involve the following evaluation methods:

- SE1: Attendance and Active Participation
- SE2: Submission and/or Presentation of Group Projects
- SE3: Submission and/or Presentation of Individual Projects
- SE6: Exams and Quizzes

These are to be weighted as follows:

- SE1: 5%
- SE2: 10%
- SE5: 15%
- SE6: 70%

6.1. GENERAL CONSIDERATIONS

Students will be evaluated continuously over the course of the semester, considering attendance and student commitment and participation in class, as well as the completion of written and graphic assignments as assigned per the syllabus. There will also be three examinations, two along the semester and one at the conclusion of the semester.

Each student has the possibility to complete the course along 4 consecutive evaluation calls.

After each lecture the students will be given some exercises or assignments to do at home to reinforce what was covered in that session. Students will be expected to have worked through these exercises and have sent them in to the professor before the following session. They will have an opportunity to discuss with the professor any issues that experience difficulty with in completing these exercises. These exercises will be compulsory and will be considered in the final mark of the course. Occasionally they can be substituted by a simple control test at the beginning of the following session.

A case study developed in groups and that will be presented at the end of the semester will complete the individual assignments.

The minimum attendance allowed will be that established in the IE University regulations: those students that do not attend at least 70% of all sessions will fail the course with a 0,0 and will proceed directly to third enrollment. Students that have failed the subject in first enrollment pass to the second enrollment, except those who do not meet the minimum attendance percentage. The maximum grade a student may achieve in second enrollment is 8.

6.2. ORDINARY EXAMINATION

Exercises, assignments and simple controls

A minimum score of 4.0/10 for this component of the final evaluation is necessary to be included in the final assessment. They will count for 35% of the final evaluation mark, with the following percentage:

- 5%: Attendance and Active Participation
- 5% individual exercises and simple controls
- 15% individual case study
- 10% group assignment

The deadline for the submission of exercises and assignments must be respected, and can only be postponed under exceptional justified circumstances. Exercises that are handed in late will count as not submitted, and will have no qualification.

Tests

There will be three tests during the course. The first will take place at the end of unit 2, and will evaluate the theoretical and practical concepts explained along the previous sessions. The second one will include only the concepts developed in unit 3. Finally, the global test will include the concepts presented in all units, including the laboratory visit, and the main findings of the group exercises. The case studies presented along the different units take part too in the different tests.

The tests will count for 65% of the final evaluation mark, with the following percentage:

- 15% first test
- 15% second test
- 35% global test, but a minimum score of 4.0/10 is mandatory for the global grade, as well as 3.0/10 for both the theoretical part (Units 1 and 2) and the numerical part (Units 3 and 4).

Final mark

If the weighted mark of the exercises, assignments, simple tests and tests is 5.00 or higher, the student will be adjudged to have successfully completed the course. If the resulting mark is less than a 5.00, students will have to sit the extraordinary examination.

6.3. EXTRAORDINARY EXAMINATION, SECOND CALL

The students who do not meet the requirements mentioned above, but only if they have an assistance record of more than 70% during the course, will have a further opportunity to qualify for satisfactory completion of the course. Those qualifying for this option will need to sit a global examination covering the full contents of the course.

The final mark of this second call will be the result of the following weight:

- Individual exercises and simple controls, individual case study and group assignment count 20% distributed in the same proportion considered in the ordinary examination
- Global test counts 80%, but a minimum of 4.0/10 is required, as well as 3.0/10 for both the theoretical part (Units 1 and 2) and the numerical part (Units 3 and 4).

If the resulting mark is 5.0/10 or higher, the student will be adjudged to have successfully completed the course.

The maximum mark a student may obtain on the second call is an 8.00.

6.4. ORDINARY AND EXTRAORDINARY EXAMINATIONS, THIRD AND FOURTH EVALUATION CALLS

For those students that are on the 3rd and 4th exam sessions, the evaluation system will follow the same criteria. Considering the fact that they might not be able to attend the sessions regularly, they will be provided with the course material via e-mail or on the on-line campus. Individual and group assignments must be presented as the rest of the students, as well as simple controls that could be done online in this case.

All the tests must be done in Segovia campus at the same time than the rest of the students.

6.5. GRADING STANDARDS

According to IE University policies, the students will be evaluated on a scale from 1 to 10. The standards of each grades are described below:

- 1, 2, 3, 4: Not passing level of work -- significant areas needing improvement and/or incomplete or insufficient deliverables to evaluate student properly.
- 5: Minimum acceptable passing level of work with several areas needing critical improvement, and/or the further development of deliverables.
- 6: Fair level of work with some areas needing improvement.

- 7: Consistent, solid work during the whole semester. The student producing what is expected at that year level.
- 8: Advanced level of work for what can be expected at that year level.
- 9: Exceptional level of work, highly advanced for the student's year level. Starting at the grade of 9, the student may (according to the necessary consensus among professors) receive "Honors / Matricula de Honor/Honors" as a recognition of an exceptional work.
- 10: Beyond exceptional level of work, within the standards of a much higher year level.

criteria	percentage	Learning Objectives	Comments
Final Exam	35 %		Global test, 4/10 required (global), 3/10 required (theoretical and numerical)
Intermediate Tests	30 %		15%+15% Test1&Test2
Individual Presentation	15 %		Individual case study
Group Presentation	10 %		Grupo assignment: construction procedures
Individual Work	5 %		Individual exercises and simple controls
Class Participation	5 %		Attendance and Active Participation

RE-SIT / RE-TAKE POLICY

6.4. ORDINARY AND EXTRAORDINARY EXAMINATIONS, THIRD AND FOURTH EVALUATION CALLS

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All the tests must be done in Segovia campus at the same time than the rest of the students.

BIBLIOGRAPHY

Recommended

- J. Norman, O. Broadbent, J. F. Carr, R. De'Ath, R. Harpin, G. Knowles, I. Lloyd. *Conceptual design of buildings.* The Institution of Structural Engineers 2020. ISBN 9781906335427 (Printed)
- B. N. Sandaker, A. P. Eggen, M. R. Cruvellier. *The Structural Basis of Architecture.* Routledge 2011. ISBN 9780415415457 (Printed)
- A. Muttoni. *The Art of Structures, Introduction to the functioning of structures in architecture.* EPFL Press 2011. ISBN 9780415610292 (Printed)
- Peter Rice. *An Engineer Imagines.* Ellipsis London Ltd 1994. ISBN 9780992950132 (Printed)

- Malcolm Millais. (2017). *Building Structures: understanding the basics.* 3. Routledge. ISBN 978113811975 (Printed)

BEHAVIOR RULES

Please, check the University's Code of Conduct here. The Program Director may provide further indications.

ATTENDANCE POLICY

Please, check the University's Attendance Policy here. The Program Director may provide further indications.

ETHICAL POLICY

Please, check the University's Ethics Code here. The Program Director may provide further indications.