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| Degree Course | Second Cycle Degree Course in Architecture -Class LM-4 |
| Course code | 1001143 |
| Lecturer | ALBA SOFI |
| Course name | STRUCTURAL MECHANICS |
| Disciplinary area | Structural analysis and design for Architecture |
| Disciplinary field of science | ICAR/08- Mechanics of Solids and Structures |
| University credits - ECTS | 6 |
| Teaching hours | 60 |
| Course year | II |
| Semester | I |

## Synthetic description and specific course objectives

The Course of Structural Mechanics deals with: the kinematics and statics of deformable solids idealized as continuum media according to the Cauchy model; constitutive behaviour of materials and their strength; structural beam theory; the De Saint Venant solution for cylindrical solids and its application to beam analysis; strength assessment.

Presentation of theoretical material is always accompanied by practical examples in order to provide methodological-practical tools as well as to show the relationship between analytical models and real structures.

The students must acquire knowledge on theoretical-scientific and methodological-practical aspects of Structural Mechanics. They must be able to use such knowledge in order to analyze the physical-mechanical behaviour of structural systems and perform strength assessment of the constituent elements. From a multidisciplinary perspective, the Course will start a process of integration between the architectonic conception and the technical-scientific rigour of Structural Mechanics which will lead to the full comprehension of structural behaviour as an essential step in the design process.

## Course entry requirements

Knowledge acquired during the Course of “Mathematical Institutions” (preparatory): elementary algebra, differential and integral calculus, functions. Basic knowledge of geometry, trigonometry and matrix analysis.

Knowledge acquired during the Course of “Statics” (preparatory): theory of equilibrium; fundamentals of vector theory; statics and kinematics of rigid body; geometry of areas.

## Course programme

**Stress analysis**

Cauchy’s continuum. Definition of Cauchy’s stress. Cauchy’s theorem. Stress tensor and physical meaning of its components. Stress invariants. Principal stresses and directions. Classification of stress state: triaxial, plane, and uniaxial stress states. Equilibrium equations.

**Strain analysis**

Deformable continuum. Congruent change of configuration. Infinitesimal displacement assumption. Infinitesimal displacement in the neighbourhood of a point. Rigid rotation tensor. Strain tensor and physical meaning of its components. Strain invariants. Principal strains and directions. Classification of strain states: triaxial, plane and uniaxial strain states.

**Constitutive relationships**

Experimental tests. Elastic behaviour of materials. Brittle and ductile materials. Linear-elastic constitutive relationships for isotropic materials. Engineering elastic constants.

**Elastic equilibrium problem**

Problem formulation. Existence and uniqueness of the solution. Outline of the displacement method and force method.

**Beam theory**
Kinematic model of the plane straight beam. Euler-Bernoulli beam model. Generalized displacements and strains. Generalized forces and stresses. Equilibrium equations. Linear-elastic isotropic constitutive relationships. Formulation and solution of the elastic beam problem. Differential equation for beam deflection. Elastic and inelastic constraint settlements. Thermal distortions. Principle of virtual work for the Euler-Bernoulli beam.
Determination of elastic displacements in beam systems: differential equation for beam deflection, principle of virtual work (for statically determinate systems). Analysis of statically indeterminate systems: method of forces; principle of virtual work (Müller-Breslau equations).

**De Saint Venant problem**
Problem formulation. De Saint Venant postulate. Axial loading. Bending moment. Unsymmetrical beam bending. Torsion: circular section, analogy with other physical problems, approximate solutions for open and closed thin-walled sections. Shear force: approximate theory of Jourawsky, shear centre, compact sections, open and closed thin-walled sections.

**Elastic limit**
Failure criteria for brittle materials: Galileo-Rankine criterion (maximum normal stress). Failure criteria for ductile materials: Huber-Von Mises and Tresca (maximum shear stress) yield criteria. 2D and 3D elastic domains. Strength assessment by the allowable-stress method.

## Expected results

**Knowledge and understanding** (Dublin descriptor 1)
Knowledge and understanding of theoretical and practical topics concerning: the kinematics and statics of deformable solids idealized as continuum media according to the Cauchy model; constitutive behaviour of materials and their strength; structural beam theory; the De Saint Venant solution for cylindrical solids and its application to beam analysis; strength assessment. This will be achieved through lecture attendance and the use of advanced textbooks.

**Applying knowledge and understanding** (Dublin descriptor 2)
The ability to apply theoretical knowledge to define a mathematical model of a real structural problem taking into account the behavior of the constituent material and then to analyze structural response by applying appropriate solution methods. In particular, the student must be able to solve statically indeterminate plane beam systems under prescribed loads by determining the constraint reactions, the diagrams of internal forces, the displacements, the diagrams of strains and stresses in critical sections. Furthermore, the student must be able to select and apply a suitable failure criterion to assess material strength by the allowable-stress method.

**Making judgments** (Dublin descriptor 3)
The ability to interpret the results obtained from the analysis of structural systems (constraint reactions, diagrams of internal forces, displacements, strains and stresses) and their application in the design practice.

**Communication skills** (Dublin descriptor 4)
The ability to: i) communicate theoretical knowledge by adopting a terminology specific to the Mechanics of Solids and Structures; ii) describe structural problems and related solution methods; iii) graphically represent and interpret the results obtained from the analysis of structural systems.

**Learning skills** (Dublin descriptor 5)
The ability to learn the theoretical and practical contents of the Course through lecture attendance and independent work. This will allow the student to undertake the study of related disciplines.

## Course structure and teaching

Frontal lectures (hours/year in class): 36
Practical classes (hours/year in class): 24
Optional guided practical classes outside of class time (hours/year in class): 10

**Calendar of teaching activities**
Week 1-4: Theoretical topics
Week 5: Practical classes
Week 6: Theoretical topics
Week 7: Practical classes
Week 8: Theoretical topics

Week 9: Practical classes
Week 10: Theoretical topics
Week 11: Theoretical topics and practical classes
Week 12: Practical classes

## Student’s independent work

Student's independent work will consist of the following activities (90 hours):
- in-depth study, using textbooks, of the topics covered during the frontal lectures;
- solve practical examples concerning statically indeterminate beam systems, evaluation of displacements of statically determinate structures, stress analysis of De Saint Venant solid, strength assessment by the allowable-stress method;
- carry out homework assigned by the Lecturer and mandatory for admission to final exam.

## Testing and exams

Learning will be verified at an intermediate and final stage.
The intermediate verification will consist of handing in mandatory homework for admission to the final verification phase. The homework can only be handed in by students who have achieved an attendance of not less than 70 percent (Art. 14 of the Didactic Regulations).
The final examination (profit exam) will consist of a written test including questions of either an applied (2 or 3) or theoretical (2 to 4) nature, and an oral examination on the topics covered in the Course.
The written test and the oral examination will be held in the same session. No books, notes, or electronic devices can be used during the written test.
The grade, expressed in thirtieths, will be awarded based on the level of achievement of the expected results according to the Dublin indicators.

## Suggested reading materials

Theory:
-Paolo Casini, Marcello Vasta, Scienza delle Costruzioni. Quarta edizione. Città Studi, Novara, 2019.
Ferdinand P. Beer, E. Russel Johnston, Jr., John T. DeWolf, David F. Mazurek, Meccanica dei solidi. Elementi di Scienza delle Costruzioni. Edizione italiana a cura di Massimo Cuomo. V edizione. McGraw-Hill Education, Milano, 2014.
Claudia Comi, Leone Corradi dell’Acqua, Introduzione alla Meccanica Strutturale. Terza edizione. McGraw-Hill Education, Milano, 2012.

Applications:
-Erasmo Viola, Esercitazioni di Scienza delle Costruzioni. Vol. 2. Pitagora Editrice, Bologna, 1993.