COURSE OF: **STRUCTURAL DESIGN** (6 CFU) - ACADEMIC YEAR 2020/21
STUDY PROGRAMME: SUSTAINABLE BUILDING ENGINEERING
THIRD YEAR BACHELOR PROGRAMME - FIRST SEMESTER

PROFESSOR'S NAME: Francesco Petrini Ph.D., Assistant Professor at the Department of Structural and Geotechnical Engineering, Via Eudossiana, 18 00184- Roma
PHONE NUMBER: +39 0644585072
E-MAIL ADDRESS: francesco.petrini@uniroma1.it

EXPECTED LEARNING OUTCOMES:
The course focuses on structural design, through the translation of the principles and theories of structural mechanics into models, methods and criteria suitable to define the structural behavior of buildings and to perform the verification of safety and performance capabilities of simple works and steel elements, in reinforced conglomerate.

LEARNING OBJECTIVES:
Upon completion of the course, the students:
1) will acquire the theoretical and methodological knowledge fundamental for structural analysis and design; 2) will have the skills to conceive, design and verify ordinary constructions; will acquire skills 3) of judgement and 4) communication of ideas, data, problems and solutions related to constructions typical of Civil Engineering; 5) will subsequently be able to extend the knowledge and skills on all specialized topics related to Structural Engineering.

COURSE DESIGN
Due to the COVID-19 emergency, the course will be delivered in blended modality: remotely and in person (in all cases by providing the live streaming transmission of the lecture), according to the schedule reported below. For the live streaming, tools such as *Google Meet, Microsoft Teams or Zoom* could be used.

PROGRAM
Part I: Structural analysis for design.

- Definition of construction and of structure. Identification of the structural scheme. Constraints. Loads and their path within the structure. Processes of structural analysis and design (synthesis). Definition of calculation and design models. Position of the Structural Design course compared to the other courses of Structural Engineering and Civil Engineering.
- Fundamental structural requirements. Strength, stiffness, stability, ductility, durability, robustness. Equilibrium path, limit points and bifurcation points. Imperfections. Linear and non-linear systems. Operating and collapse conditions of a structure. Definition of limit states. Fragile and ductile structural behaviour and parallel coupling of elements with different characteristics.
- Definition of the structural problem. Organization of the data of the problem. Structural system. Principle of effects superposition. De Saint Venant principle. Bernoulli-Navier regions (B-regions) and diffusive regions (D-regions). Recurrent structural typologies: inextensible axial elements, beam elements rigid in bending - rigid diaphrams, fixed and movable nodes frames, shear-type frames, multi-storey framed structures, bracing elements and bracing walls. Foundation elements. Qualitative analysis of elastic deformation of framed structures.
- Limit analysis. Elastic and plastic behaviour. Definition of plastic hinge. Sectional redistribution coefficient. Failure domains. Cross-section utilization factor. Collapse multiplier
- Structural reliability. Verification formats. Capacity and Demand in performance. Verification levels: punctual, sectional, elemental, global. Probabilistic and semi-probabilistic reliability formats. Total and partial safety coefficients. Limit State method. Ultimate and Serviceabiltity Limit States.
- Actions on structures. Classification and characteristics. Description and combination of actions. Stresses envelope.

Part II: Steel Structures.

- Material properties. Experimental tests for the definition of the characteristics and their conventionality. Industrialized elements, morphology and use, identification of connections.
- Structural elements in tension and compression. Eulerian critical buckling load. Analysis of the phenomenon of instability in industrial sections. Global and local buckling phenomena. Flexural instability in elements.
- Steel connections. Typologies. General considerations on joints and their effects on the behavior of the global structural behavior. Bolted and welded joints. Regular and friction bolts. Composition of beams.
- Common types of steel structures. Reticular structures. Buildings with pendulum columns. Substructures. Bracing elements. Strength checks. Ultimate Limit States. Functionality checks. Serviceability Limit States. Structural Robustness.

Part III: Reinforced Concrete structures (R.C.)

- Material characteristics. Technology. Experimental behavior. Breaking criteria and constitutive laws for concrete. Biaxial stress states. Considerations on the coupling between concrete and steel. Bonding forces. Ultimate Limit States axial failure domains. Construction layouts for longitudinal/transverse reinforcement. Containment effects. Ductile and brittle collapses.
- Verification format. Ultimate Limit States. Serviceability and Limit States. Axial action, bending, shear, torsion. Interaction between the various stresses. Resistance domains. Free and conditioned design methods. Minimum reinforcement. Fragility phenomena. Buckling of slender elements in R.C. Cracking and deformation boundary states.
- Reinforced concrete buildings with framed structure. Structural modelling. Structural sections. Critical sections. Nodal regions and modeling with strut-and-tie patterns. Special construction elements. Short cantilever beams. Foundation elements. Floor Slabs. Construction layouts.

ATTENDANCE: attendance is **expected** and strongly recommended (70% attendance, minimum threshold to take the exams)

Essential REFERENCES.

- (Part I). D.K. Ching, B. S. Onouye, D. Zuberbuhler, Building structures illustrated, Wiley.
- (Part II) T.V. Galambos, F.J. Lin, B.G. Johnston (1996). Basic Steel Design with LRFD. Prentice Hall, Upper Side River, New Jersey, USA
- (Part III) W.H. Mosley, J.H. Bungey & R. Hulse (1999). Reinforce Concrete Design. MacMillan press, London, UK.

Suggested References (in Italian)

- (Parts I and II) F. Bontempi, S. Arangio, L. Sgambi (2008). Tecnica delle Costruzioni, Basi della progettazione. Elementi intelaiati in acciaio, Carocci Editore.
- (Parts I, II and III) B. Furiozzi, C. Messina, L. Paolini. Prontuario per il calcolo di elementi strutturali.
- (Parts I, II and III) Norme Tecniche Costruzioni (DM 17/01/18); Istruzioni CNR10011/97; Eurocodici.

ONLINE TEACHING MATERIAL AND TEACHER-STUDENTS COMMUNICATIONS

- *Online page of the course* (https://corsidilaurea.uniroma1.it/en/users/francescopetriniuniroma1it): the teacher will provide news and announcements about the course
- *Google Classroom* (course code: **dka7yh5**): the teacher will provide teaching material and news about the course
- *Teacher's Personal Webpage*, Teaching section (https://sites.google.com/a/uniroma1.it/francescopetrini-eng/Teaching): the teacher will provide teaching material and news about the course

LECTURES SCHEDULE - NOTE: days, dates and modalities are subject to changes

Part	*Lecture No*	*Day*	*Date*	*Time*	*Modality*	*Contents*
I	1	Wed	*Sept 30th*	09:00-11:30	Remotely	Position of the Structural Design course compared to the other courses of Structural Engineering and Civil Engineering. Identification of the structural scheme. Constraints. Loads and their path within the structure. Processes of structural analysis and design (synthesis). Definition of calculation and design models.
	2	Thu	*Oct 1st*	11:30-13:30	In person (with live streaming)	Strength, stiffness, stability, ductility, durability, robustness. Equilibrium path, limit points and bifurcation points. Imperfections. Definition of limit states.
	3	Wed	*Oct 7th*	09:00-11:30	Remotely	Linear and non-linear systems. Operating and collapse conditions of a structure. Eulerian buckling
	4	Thu	*Oct 8th*	11:30-13:30	In person (with live streaming)	Qualitative analysis of elastic deformation of framed structures. Fragile and ductile structural behaviour and parallel coupling of elements with different characteristics.
	5	Wed	*Oct 14th*	09:00-11:30	Remotely	Organization of the data of the problem. Structural system. Principle of effects superposition. De Saint Venant principle. Bernoulli-Navier regions (B-regions) and diffusive regions (D-regions).
	6	Thu	*Oct 15th*	11:30-13:30	In person (with live streaming)	Recurrent structural typologies: inextensible axial elements, beam elements rigid in bending - rigid diaphragms, fixed and movable nodes frames, shear-type frames, multi-storey framed structures, bracing elements and bracing walls. Foundation elements.
	7	Wed	*Oct 21th*	09:00-11:30	Remotely	Verification formats. Capacity and Demand in performance. Verification levels: punctual, sectional, elemental, global. Probabilistic and semi-probabilistic reliability formats. Total and partial safety coefficients. Limit State method. Ultimate and Serviceability Limit States.
	8	Thu	*Oct 22th*	11:30-13:30	In person (with live streaming)	Elastic and plastic behavior. Definition of plastic hinge. Sectional redistribution coefficient. Failure domains. Cross-section utilization factor. Collapse multiplier
	9	Wed	*Oct 28th*	09:00-11:30	Remotely	Demand analysis. Description and combination of actions. Stress envelope.
II	10	Thu	*Oct 29th*	11:30-13:30	In person (with live streaming)	Steel Structures. Experimental tests for the definition of the characteristics and their conventionality. Industrialized elements, morphology and use, identification of connections.
	11	Wed	*Nov 4th*	09:00-11:30	Remotely	Industrialized elements, morphology and use, identification of connections
	12	Thu	*Nov 5th*	11:30-13:30	In person (with live streaming)	Steel Structures. Eulerian critical buckling load. Analysis of the phenomenon of instability in industrial sections. Global and local buckling phenomena. Flexural instability.
	14	Wed	*Nov 11th*	09:00-11:30	Remotely	Steel connections. Typologies. General considerations on joints and their effects on the behavior of the global structural behavior. Bolted and welded joints. Regular and friction bolts. Composition of beams.
	15	Thu	*Nov 12th*	11:30-13:30	In person (with live streaming)	Common types of steel structures. Reticular structures. Buildings with pendulum columns. Substructures. Bracing elements. Strength checks. Ultimate Limit States. Functionality checks. Serviceability Limit States. Structural Robustness

LECTURES SCHEDULE (cont.) - NOTE: days, dates and modality are subject to changes

Part	***Lecture No***	***Day***	***Date***	***Time***	***Modality***	***Contents***
III	16	Wed	*Nov 18th*	09:00-11:30	Remotely	Reinforced Concrete structures (R.C.). Technology. Experimental behavior. Considerations on the coupling between concrete and steel. Material characteristics and constitutive laws for concrete
	17	Thu	*Nov 19th*	11:30-13:30	In person (with live streaming)	R.C. Structures. Ultimate Limit States axial failure domains. Biaxial stress states. Bonding forces.
	18	Wed	*Nov 25th*	09:00-11:30	Remotely	R.C. Structures. Construction layouts for longitudinal/transverse reinforcement. Containment effects. Ductile and brittle collapses
	19	Thu	*Nov 26th*	11:30-13:30	In person (with live streaming)	Verification format. Ultimate Limit States. Serviceability and Limit States. Axial action, bending, shear, torsion. Interaction between the various stresses. Resistance domains.
	20	Wed	*Dec 2nd*	09:00-11:30	Remotely	Free and conditioned design methods. Minimum reinforcement. Fragility phenomena. Buckling of slender elements in R.C. Cracking and deformation boundary states.
	21	Thu	*Dec 3rd*	11:30-13:30	In person (with live streaming)	Applicative design of a R.C. frame structure. Part I.
	22	Wed	*Dec 9th*	09:00-11:30	Remotely	Applicative design of a R.C. frame structure. Part II.
	23	Thu	*Dec 10th*	11:30-13:30	In person (with live streaming)	Applicative design of a R.C. frame structure. Part III.
	24	Wed	*Dec 16th*	09:00-11:30	Remotely	Applicative design of a R.C. frame structure. Part IV.