

Insegnamento: TUNNELS AND UNDERGROUND STRUCTURES	
CFU: 9	SSD: ICAR/07
Lectures: 55	Tutorials: 20
LAUREA MAGISTRALE IN INGEGNERIA STRUTTURALE E GEOTECNICA – Year II	
Course objectives: Due to the increase of social demand for sustainable mobility in large urban areas, underground works involving tunnelling in densely urbanised areas increased in recent years. The aim of the course is to illustrate to the students the main geotechnical issues related to tunnelling and underground construction, particularly in urban areas. The fundamentals of tunnel design and the most common methodologies for tunnel construction are presented with the aid of documented case histories. Besides attending the theoretical lessons, students are involved in applied activities consisting in exercises reflecting the state-of-practice of geotechnical design of tunnels	
Course contents: Geotechnical Investigation for Tunnel Construction. Investigations at typical stages of a tunnel project. Rock rating and classification. Special tests for TBM excavation. Tunnel Stability. Limit analysis theorems. Stability of a plane strain circular opening in drained and undrained conditions. Stability of circular heading in drained and undrained conditions. Local stability. Stability of openings in rock mass. Tunnel Construction Techniques. Heading. Drill and blast excavation. Open face excavation. Tunnelling shields and Tunnel Boring Machines. Cut and cover tunnelling. Tunnelling waste and muck removal. Stresses around Tunnels. Stresses and deformation around an elastic cavity. Plane strain and axisymmetric conditions, supported and unsupported cavity in isotropic primary stress. Anisotropic primary stress. Anisotropic elastic ground. Circular cavity in elastoplastic ground. Ground and Support Reaction Lines. Stresses around tunnel heading. Stresses around a spherical cavity. Principles of Tunnel Lining Design. Arching. Ground-support interaction: continuum methods, bedded-spring models, convergence-confinement method. Examples of calculation methods. Lining systems. Sprayed Concrete Lining. Cast-in-situ concrete lining. Pre-cast segmental lining. Ground Improvement Techniques. Ground Reinforcement. Ground Freezing. Grouting. Ground Movements. Sources of ground movement around tunnel excavation. Empirical method of prediction. Analytical methods. Numerical methods: effects of soil non-linearity, anisotropy, small strain stiffness, and recent stress history. Influence of the building stiffness on the settlement profile, modification factors. Evaluation of relative stiffness parameters for masonry bearing walls, framed structures, façades with openings. Assessment of risk of damage to buildings. Protective measures: in-tunnel measures, ground treatment, compensation grouting, barriers. Seismic Behaviour of Tunnels and Underground Structures. Seismic behaviour and damage of cylindrical long underground structures (tunnels and pipelines): examples. Damage patterns and classification. Fragility curves. Fundamentals of seismic site response analysis. Methods of analysis: transversal section, coupled and uncoupled approach; simplified methods; analysis in longitudinal direction. Monitoring and control in Tunnel Construction. Quality of measure. Types of instrumentations for tunnel construction. Observational method. Examples.	
Lecturer: EMILIO BILOTTA	
Exam Code: 32235	Term: II
Requirements / Prerequisites: None	
Teaching Method: Lectures, Classworks, Tutorials, Seminars on Case studies, Site visits.	
Learning material: - Lecture notes and slides - D.Kolymbas, Tunnelling and Tunnel Mechanics, Springer - D. Chapman et al., Introduction to Tunnel Construction, Spon Press	
Final exam: Oral exam on course contents and discussion on classworks	