

# "Design and Construction of Underground Works". A Postgraduate Course in the National Technical University of Athens

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**ABSTRACT:** The construction of underground works has recently grown considerably worldwide, mainly for the development of communication infrastructures. Advances in engineering offer today the necessary background to implement underground projects, mainly tunnels and chambers of such size and under such adverse conditions that a few decades ago their construction would have been impossible. To assure the current and future availability of proper human resources that would be able to carry out the challenges of the design and construction of such underground works, a postgraduate course is established since 1998 jointly by the Schools of Mining Engineering and of Civil Engineering in the National Technical University of Athens. The postgraduate course covers four major fields: Engineering Geology and Ground Investigation; Design; Construction and Monitoring; Management. The course leads to the "Post Graduate Specialization Diploma" in the area of the "Design and Construction of Underground Works" after the successful completion of one calendar year of courses and the preparation of a thesis. The paper gives details of the structure of this course aimed to produce specialized graduates for the Civil and Mining Engineering industry.

## 1. INTRODUCTION-OBJECTIVES

The aim of the postgraduate course "Design and construction of Underground Structures" in the National Technical University of Athens (NTUA) is to offer specialized knowledge at a high level, through rigorously structured courses of lectures, tutorials, laboratory and field work, specialized workshops and the completion of a thesis at the end of the course.

The necessity of such a postgraduate course emerges from the considerable worldwide growth of tunnelling and underground construction for the improvement of existing or the planning and construction of new communication infrastructure, new hydraulic routes, and the need of extended subsurface use in urban development and storage areas. The evolution of technology allows today the implementation of financially favorable construction methods under adverse geological conditions demanding special design solutions and particular excavation techniques.

In Greece the recent and continuing construction of tunnels and metro works, in difficult geological conditions and weak ground

conditions offers an excellent opportunity to provide a full scale model for educational purposes and in situ work and training.

Additionally, students have the opportunity to be enrolled for a PhD degree via this postgraduate programme.

## 2. SUPPORTING SCHOOLS AND ADMINISTRATION

The course is offered through a collaboration of the School of Mining Engineering and the School of Civil Engineering of NTUA and administrated by a special Committee consisting of nine members. It is taught jointly by the Department of Geotechnical Engineering and the Department of Management of the School of Civil Engineers and the Departments of Mining and of Geological Sciences of the School of Mines.

## 3. DURATION OF THE COURSE

The duration of the course for a full time student is one calendar year divided into three terms of four months each. Extension of the above period is not

generally granted, unless the student is registered as a part – time student and completes the course in two years. The two first terms are devoted to lecture courses and associated activities such as tutorials, laboratory and field work, while the third term is devoted to the preparation and presentation of a dissertation. The course commences each October.

#### 4. COURSE STRUCTURE

The postgraduate course is developed in the following fields:

- Geological model, ground investigation, ground behaviour, design parameters
- Design of underground works
- Construction (conventional, mechanized) and monitoring
- Organization and Management

Each of these fields is supported by a series of compulsory and optional lecture courses, together with tutorials, laboratory work, field work and attendance of invited lectures.

Each student must pass eight (8) lecture courses each term out of which seven (7) are compulsory and one (1) optional. The total weekly hours per semester do not exceed 18. Each lecture course is taught for 2 to 3 hours weekly. One day of the week is dedicated to lectures from invited speakers, academics, experts, consultants or contractors.

The lecture courses are:

##### - 1st TERM

##### Compulsory Courses

- Engineering Geology for Underground Works
- Ground Investigation
- Advanced Rock Mechanics
- Design of Underground Works
- Design and Feasibility Analysis of Underground facilities
- Organization and Management of Underground Projects
- Mechanics of Continuous Medium

##### Optional (1 subject must be selected)

- Instrumentation in Geotechnical Engineering
- Electrical and Mechanical Installations – Ventilation
- Ground water and their Confrontation.

##### - 2st TERM

##### Compulsory Courses

- Numerical Methods of Analysis
- Drilling and Blasting Techniques for Underground Works
- Reinforcement and Support Systems
- Mechanized Excavation of Tunnels
- Shallow and Urban Tunnels – Retaining Structures – Ground Settlements

- Tunnel portals
- Equipment for Excavation, Loading and Transportation

##### Optional (1 subject must be selected)

- Construction Management Information Systems
- Techno-Economic Decision Analysis
- Risk Management in Issues of Safety and Health
- Earthquake resistant design of Tunnels.

Written examinations take place at the end of each term.

At the end of the 1st term a compulsory field trip to tunnels under construction takes place. During this one week long trip a group project is assigned to 2 to 3\* students each day. At the end of the second term an optional 10 days tour takes place in Europe, focused mainly at the base tunnels under construction (Gotthard, Lyon-Torino).

#### 5. ADMISSION

Civil and Mining Engineers with a 5 year degree are eligible for acceptance to the course after a selection procedure based on academic performance. Other engineering disciplines and geologists are also eligible under certain additional obligations, provided they have already an MSc degree in Engineering Geology or Geotechnics and/or a substantial experience.

About 100 candidates apply for the course each year and 20 are successful.

The selection is based on the performance of the candidates during their undergraduate studies, their final year diploma thesis and their knowledge in software applications, the English and/or other languages. Previous experience in design and construction and letters of recommendation are co-evaluated. Students with experience from the tunnelling or civil works industry are welcome and it is aimed to cover 30% of the places in the course. Such students can share their experience from practice with the other students who have just obtained their first degree.

#### 6. INFRASTRUCTURE

Besides the support of the laboratories of Soil Mechanics, Foundation and Engineering Geology, Rock Mechanics and Mining Technology of the two participating Schools, the postgraduate course

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\* An example: in the 2007 field trip, tunnel design and construction were related with: active faults, karstic rocks, weak and squeezing rock masses, cataclases, clays, rock masses with frequently varying nature or anisotropic behaviour, strong but weathered rocks, unstable slopes.

has its own library facilities, specialized software applications and working space in a PC laboratory.

## 7. RESULTS

The course has already a life of 10 years and so far the postgraduate degree has been awarded to 182 graduates with the following distribution:

- Civil Engineers: 58%
- Mining Engineers: 31%
- Geologists: 5%
- Mineral Resources Engineers: 3%
- Other: 2%

Our postgraduates are in constant demand. This includes:

- Public sector (Ministries, State Companies): 30%
- Design Companies: 30%
- Construction Companies: 15%
- Academia: 1%
- Irrelevant to Tunnelling: 6%
- No data: 18%

The students fill every year a questionnaire where they express anonymously their opinion for the content of lectures and organization of the course. The answers to all questions give rates corresponding to more than 80% in satisfaction.

## 8. CONCLUSIONS

The course leads to the “Post Graduate Specialization Diploma” in the area of the “Design and Construction of Underground Works” (<http://www.ntua.gr/tunnelling/>).

The course has been evaluated from external reviewers who concluded that “The postgraduate programme “Design and Construction of Underground Works” is unique in Greece”. The reviewers recognize the course as high quality from any point of view and particularly useful and strongly recommend and suggest its support. They acknowledge that “the postgraduates have clearly increased prospects for their professional careers”. The course has already obtained the official agreement from the central admission for its continuation, before its reconsideration, until 2011.

In our knowledge, at present two postgraduate courses on Tunnelling are running in Europe, all in English language: “Tunnelling and Tunnel Boring Machines” in the Polytechnico di Torino (every other year) ([www.formazione.corep.it/gallerie.htm](http://www.formazione.corep.it/gallerie.htm)) and “Tunnelling – an International Advanced Training Programme” in the Ecole Polytechnique de Lausanne (since this year) ([www.lmr.epfl.ch/mas](http://www.lmr.epfl.ch/mas)), while a new course “NATM Engineer” will be jointly organized from 2009 by the Graz University of Technology and the University of Leoben ([NATM@tugraz.at](mailto:NATM@tugraz.at)).