Geotechnics for Civil Engineering in an Integrated Master Course

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ABSTRACT: The recently adopted curriculum of Geotechnics for Civil Engineering in the Department of Civil Engineering & Architecture at the Instituto Superior Técnico (Technical University of Lisbon) is presented and justified. This subject is dealt with taking into account the most recent reforms of the Higher Education in Portugal.

1 INTRODUCTION

A recent reform took place in the Engineering Education at the Instituto Superior Técnico (Technical University of Lisbon), mainly related with the so called Bolonha process and to the new law for the Higher Education system in Portugal.
The main aspect was the creation of a five years Integrated Master Course (instead of the former five years Degree of "Licenciatura" in Engineering, plus one more year to obtain the Degree of Master). Besides, the first three years of the Integrated Master Course allow the attainment of the Degree of "Licenciatura" in Engineering Sciences, but it is not intended that this degree habilitates to the exercise of the engineering profession. It must be emphasized that only some High Schools were allowed to teach Integrated Master Courses, mainly depending on the level of their research activities.
The model for engineering teaching in the IST is based on the development of a diversified set of competences to assure the students conditions of professional integration similar to those proportioned by the higher education institutions of reference in the European space.
Resuming, there are the following cycles of study: a first cycle of three years to obtain the degree "Licenciatura", a second cycle of two years for the degree of Master and a third cycle of one year, the PhD Programme, before starting the research work leading to the PhD degree.

Naturally this implied important modifications on the structure of the engineering courses, namely in the course which is the object of our attention, i.e., the Integrated Master in Civil Engineering at the Instituto Superior Técnico. But our interest will be focussed only on the new curriculum adopted in the area of Geotechnics for Civil Engineering in the context of the referred Integrated Master course. Some information is also given about the PhD course.

2 THE NEW CURRICULUM IN GEOTECHNICS FOR CIVIL ENGINEERING

In the following, the information regarding the curriculum concerning the geotechnical disciplines of the Integrated Master in Civil Engineering will be presented according to each one of the two first cycles. But to have a complete idea of all the disciplines and their sequence they will be presented in the following with some short comments.

2.1 *First cycle*

It corresponds to the "Licenciatura" in Engineering Sciences, i.e., Mathematics, Physics, Chemistry, Geology, Mechanics, Strength of Materials, etc. Regarding the geotechnical area two disciplines are taught in this cycle:

- Mineralogy and Geology (first year, second semester);
- Soil and Rock Mechanics (third year, second semester).
These disciplines are taught to all the students in Civil Engineering.

2.2 *Second cycle*

In this cycle of two years, the fourth year is common for all the students and the fifth year has optional disciplines, as will be seen in detail in the following points.

2.2.1 *The fourth year*

This year has two disciplines concerning the geotechnical domain that are common to all students of Civil Engineering:
- Analysis of Geotechnical Structures (fourth year, first semester);
- Geotechnical Works (fourth year, second semester).
These two disciplines tackle subjects related to the fundamental engineering concepts, namely the safety of the geotechnical structures and their behaviour in service.
It is important to underline the sequence without any discontinuity of these three disciplines (Soil and Rock Mechanics, Analysis of Geotechnical Structures and Geotechnical Works) in order to motivate students for the specialization in Geotechnics that is referred immediately bellow.

2.2.2 *Area of Specialization in Geotechnics*

The optional geotechnical disciplines of this area of specialization are taught in the first semester:
- Advanced Modelling in Geotechnics (fifth year, first semester);
- Retaining Structures and Underground Works (fifth year, first semester);
- Foundations and Earth Fill Works (fifth year, first semester);
- Geotechnical Earthquake Engineering (fifth year, first semester);
These four disciplines are options for those students who choose Geotechnics Area. The aim of these disciplines is to cover all types of geotechnical structures and to go deeper on theoretical and practical matters of the Geotechnics for Civil Engineers.
It is mandatory to add three more disciplines:
- Concrete Structures II (fourth year, second semester);
- Two free options (fifth year, second semester).

2.2.3 *Dissertation for the Degree of Master*

The work related with the dissertation is developed during the second semester of the fifth year. As was said, this semester also incorporates two optional disciplines. Naturally, the preparation of the thesis can be initiated before this last semester.
It must be stressed that any title or designation is allowed due to the frequency of a specialization area. All the students leaving the civil engineering branch of the Department of Civil Engineering & Architecture of the IST have the only title of Master in Civil Engineering, no matters the specialization area they had decided to frequent.

2.3 *The PhD Programme in Civil Engineering*

The objectives of the PhD degree in Civil Engineering are the development of knowledge in this engineering area or in associated scientific areas (PhD in Engineering Sciences). The PhD programme follows teaching and research methods prepared to give a better understanding of the theoretical and practical problems related to the practice of Civil Engineering. It consists of teaching courses (around five post-graduate courses) and a research thesis. Students with the teaching courses of a Master degree may be allowed to develop only the research thesis to obtain the PhD degree. The PhD programme has an average duration of three years and can be performed in Portuguese or in English.

3 THE GEOTECHNICAL DISCIPLINES OF THE INTEGRATED MASTER IN CIVIL ENGINEERING

To have a better idea about the geotechnical components of the Integrated Master in Civil Engineering, the main aspects of the curriculum of the disciplines related with Geotechnics are presented and commentaries are also added when necessary.

3.1 *Mineralogy and Geology*

Mainly devoted to the geology, it tackles aspects so different as the earth's crust, the geological processes, the stratigraphy and the age of soils and rocks (with a particular emphasis on the Portuguese territory), depositional environments and recent geological events such as deposition, erosion, folding, faulting and volcanic activity, trying to highlight the importance of the Geology in Geotechnical Engineering for Civil Engineering.

3.2 *Soil and Rock Mechanics*

The main objective is that the student understands the mechanical behaviour of soil and rock. Besides the fundamentals of soil mechanics it is worthy to

note that the adopted approach to describe the mechanical behaviour of soils is all based on the critical states soil mechanics (taught in IST since the year 2000). Mechanical behaviour of rock and rock masses are also introduced.

3.3 *Analysis of Geotechnical Structures*

It is intended that the student will be apt to apply the mechanics of the main problems of geotechnical structures to the cases of retaining walls, slopes and shallow foundations. Special attention is paid to the lower and upper bound theorems as well to plasticity limit analysis and limit equilibrium. The understanding of the safety principles embodied in the Eurocode 7 is also one of the main aims, as well as the adequate application of the code to simple cases of geotechnical structures.

3.4 *Geotechnical Works*

The student is prepared to deal with problems of the geotechnical structures taking into account in situ and laboratory testing as well as the design, construction and monitoring. Attention is given to the contributions of applied geology.
Diversified structures like retaining walls, shallow and deep foundations, tunnels, deep excavations, embankment dams and stabilization of slopes are considered. Ground treatment including compaction is dealt with and the role of the observational method is underlined.

3.5 *Advanced Modelling in Geotechnics*

The main aim is to familiarize the students with constitutive models applicable to geotechnical materials in order to be used in the numerical modelling of geotechnical structures for the verification of the limit states.
Constitutive equations from the classical soil mechanics (envisaging ultimate limit states) as well as from our days (focussed in the serviceability and ultimate limit states) are presented and their role discussed. The applications of the linear and non linear elasticity (K-G models), the hypoelasticity (namely the hyperbolic model) are presented, as well as the perfect plasticity (associated and non associated Mohr-Coulomb model) and the strain hardening or softening elastoplasticity (Mohr-Coulomb and Cam Clay models).
Unsaturated soils and the use of the Barcelona Basic Model are dealt with. The mechanical behaviour of rockfills is discussed at the light of most recent research works.

3.6 *Retaining Structures and Underground Works*

This discipline tackles the design of this type of structures regarding ultimate and serviceability limit states. Flexible retaining walls taking into account earth, water and surcharge pressures, base stability, struts, anchors, vertical stability and global stability. The use of the earth reinforcement (nails in particular) and to the design of reinforced earth and of nailed excavations will be introduced. Slope stabilization and stabilizing solutions, highlighting the extreme importance of drainage and of the calculation methods to evaluate the effects of the stabilizing solutions are presented.
Considerations of tunnels and other underground works focussing in the principles of these underground structures, the importance of the stability of the front face, the main role of the construction techniques the design methods and the definition of supports (primary and definitive).
Prediction and modelling of the behaviour of retaining structures and underground works will be an important aspect of the discipline. Considerations about the instrumentation and monitoring of these structures are made and some case studies will be presented.

3.7 *Foundations and Earth Fill Works*

Concerning shallow foundations, special solutions are presented and the case of the beam on an elastic medium is analyzed. Piles under vertical compression and tension, under horizontal loads and under dynamic loading are studied as well as the pile load testing.
Regarding embankment dams, subjects like site studies, selection of natural materials and design of earth and rockfill dams will be presented as well as the study of filters and drains. The importance of dam foundations, grout curtains on the dam safety is underlined. Procedures for the seepage analysis and for the stress-strain calculations of the dam body and its foundation are presented. Construction techniques, instrumentation and monitoring are taken into account and some case studies are presented and discussed. .

3.8 *Geotechnical Earthquake Engineering*

The subjects of seismology and earthquakes, wave propagation and attenuation are introduced. Soil behaviour under cyclic loading as well as their stiffness and dumping are studied. The importance of local site effects is underlined as well as the role of the transfer functions.
Applications to the design (under seismic actions) of piles and foundations loaded on the top are dealt with. Dynamic impedance functions are studied. Seismic response of retaining structures, seismic pressures and seismic response of slopes are considered. The concepts of cyclic mobility and liquefac-

tion are introduced and the evaluation of liquefaction susceptibility is presented.
Recommendations for analysis and design in reference to the Eurocode 8 are important considerations due to their practical reflexes.

4 FINAL REMARK

Description and considerations about the disciplines of the geotechnical area of an Integrated Master Course in Civil Engineering were presented. This geotechnical content shows the importance and specificity of this subject, mainly due their structural analysis and safety concepts, which are also the distinctive core of other Civil Engineering areas.