Civil and environmental engineering education with focus on geotechnical training in Germany

Études et formation pour les ingénieurs en genie civil et d´environnement avec un accent sur la géotechnique en Allemagne

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ABSTRACT
Geotechnical engineering is an indispensable element of the education of civil engineers at German universities. In the following the German system of civil engineering education and the geotechnical curricula, in particular the new Bachelor and Master programs, at German universities are described and presented. In the end the authors give an overview of further Bachelor and Master programs for environmental engineering, facility management and energy engineering, which are strongly connected with the education and training of geotechnical and geoenvironmental engineering.

RÉSUMÉ
La géotechnique fait traditionnellement partie de la formation des ingénieurs en génie civil dans les universités allemandes. Dans la suite de ce dossier, le programme allemand pour les études d'ingénieur du génie civil ainsi que le curriculum géotechnique seront décrits et présentés, en particulier les nouveaux programmes du Bachelor et du Master des universités allemandes. Pour finir les auteurs donneront un aperçu des futurs programmes du Bachelor et du Master en ingénieur d'environnement, en "facility management" et en ingénieur d'énergie. Ces matières sont fortement liés aux études et à la formation des ingénieurs en géotechnique et en géotechnique environnementale.

Keywords : geotechnical and geoenvironmental engineering education, Bachelor and Master programs at German universities

1 SYSTEM OF SCIENCE-BASED CIVIL ENGINEERING EDUCATION

The science-based and research-orientated education of civil engineers is offered by Universities and Universities of Technology (Technical Universities).

1.1 *Pre-university education*

To get an admission for a German university usually 13 in some federal states 12 years of school education are required. Four years in the primary school are followed by nine years in the secondary school (High School / Gymnasium). The successful final examination is awarded with the so-called "Abitur" which is a prerequisite for an university admission.

1.2 *University education*

In total 20 universities in Germany offer programs in civil engineering education including geotechnics. The location of these universities is shown in Figure 1. As a consequence of the Bologna Convention the German universities started to change their civil engineering education from the diploma-program to the Bachelor and Master program. The contents of the education did not change.

Figure 1. Universities in Germany offering education programs for civil engineering including geotechnics.

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Usually the studies of civil engineering in the diploma-program take ten terms (five years) at most of these universities. The Bachelor of Science program takes six terms (three years) and the Master of Science programs four terms (two years). Hence, the duration and the contents of the Bachelor and the Master of Science program is equal to the diploma-program. After a successful completion of the studies at the university the degree "Dipl.-Ing." for the diploma program is awarded to the graduates. Students in the Bachelor or Master programs achieve the degrees "Bachelor of Science" and "Master of Science" respectively.

At present the education of civil engineers at many German universities changes from the single-stage Diploma course of studies to the two-stage Bachelor of Science and Master of Science course of studies. Regarding the taught contents the degree of Master of Science is identical to the degree "Dipl.-Ing.".

The diploma program for civil engineers at German universities is divided into two parts, the basic studies and the major studies. In the basic studies mathematics, mechanics, physics, chemistry etc. are taught and propaedeutic courses in civil engineering subjects are held. After a successful completion of the basic studies the results are rated with a "pre-diploma". The basic studies are then followed by major studies in civil engineering subjects. The studies are usually finished with the preparation of a diploma thesis (duration on an average of about three months).

The education in the Bachelor program starts also with basic studies, followed by a wide ranged education in the disciplines of civil engineering. The final degree is achieved with the preparation of a Bachelor thesis (duration on an average of about two months).

The studies of the Bachelor of Science program should usually be followed by the Master of Science program. On the one hand an usual civil engineering program can be continued, on the other hand offer many universities Master of Science programs with focus on special topics as e.g. geotechnical and structural engineering, environmental engineering or facility management as it will be discussed later. The contents of the Bachelor program are intensified and the students are able to choose individually subjects with special topics. The Master program is usually completed with a Master thesis (duration on an average of about 5 months).

The aims of civil engineering education at German universities are the imparting of a broad knowledge in many fields of civil engineering as well as the conveying of special knowledge in selected subjects. The ability of civil engineers or engineers in general to work interdisciplinary is very important for their success in the later job. The foundation of this ability is laid by an education in basic sciences.

The Bachelor program offers the possibility for a diversified basis education in civil engineering. The different Master studies then provide the possibility to specify in a chosen subject.

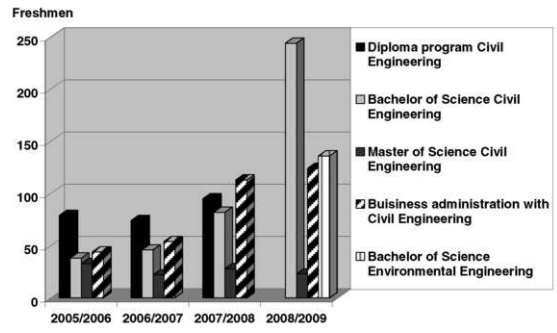

Figure 2. Freshman in Civil Engineering and Environmental Engineering at Technische Universität Darmstadt

The number of freshmen in civil engineering meanwhile increases as shown in Figure 2. 50% of the freshmen of the winter term 2007/2008 are already enrolled in the Bachelor-program. At Technische Universität Darmstadt the Diploma program in civil engineering finished with the winter term 2007/2008. The Bachelor and Master program in environmental engineering started with the term 2008/2009 with about 140 freshman. Altogether the faculty of civil engineering in Darmstadt had a number of 470 freshman in the winter term 2008/2009.

2 EDUCATION IN GEOTECHNICAL AND GEOENVIRONMENTAL ENGINEERING

2.1 *Undergraduate / graduate education*

Geotechnics is traditionally an indispensable element of the civil engineering education in Germany. All 20 German universities which are teaching civil engineering offer courses in geotechnics. The curricula of these universities differ in several courses, but there are basic courses which are part of the curriculum at almost every university. According to the curriculum at the Technische Universität Darmstadt the field of geotechnics is divided into three main subjects as soil / rock mechanics, foundation / rock / tunnel engineering and environmental geotechnics. The contents of these subjects are illustrated in Figure 3. This definition of geotechnics corresponds to the curricula of the most German speaking universities.

The geotechnical education usually starts in the 4th or 5th term in both study programs (diploma and bachelor) after finishing the basic courses. A few universities offer basic courses in geotechnics and introduction into soil mechanics and geotechnical engineering already in the 3rd term.

Some statistics concerning the number of compulsory and optional courses at German universities are shown in Table 1.

Table 1. Statistics concerning courses pertaining to the field of geotechnics at German universities.

	min	max	Average
Number of compulsory courses for the basic terms	1	5	3
Number of compulsory courses for the specialization terms	1	10	5
Number of optional courses	1	12	6

For teaching geotechnics different pedagogical methods are used. The major part of the lessons is held as lecture, normally accompanied by tutorial exercises.

In the specialization terms there are usually seminars and also laboratory work offered. Some universities provide seminars in which the students deal with real major projects. Also presentation techniques of the students are trained with the preparation of presentations to special geotechnical topics as for example the design and the construction of retaining walls.

In the laboratory the students can conduct in self-dependent manner laboratory tests for soil mechanics.

In order to get some impressions of general practical construction processes and especially geotechnical constructions excursions are organized by the departments of geotechnics.

An example for an optional cours offered by 60% of the German universities is the use of the finite-element-method for the design of geotechnical constructions. The students learn how to use qualified and with critical reflection the finite-element-method.

Due to the fact that geotechnics is strongly linked to research and constantly developing, the geotechnical education is

adapted subsequently. An example for this development is the integration of geothermal energy in the geotechnical curriculum.

Energy and questions related to energy supply, supply guarantee and energy resources influence combined with the topics climate, climate change and climate protection crucial the actual discussion in politics, economy and science. The thermal use of the subsoil (geothermal energy) as a renewable, baseload and cost-saving energy source offers a great opportunity to avoid the usage of fossil fuels and for climate protection due to CO2 reduction. It is important to implement the development in the research concerning this topic early in the geotechnical education. At almost half of the universities lectures concerning geothermal energy are already part of the curriculum. Students get to know the use of geothermal energy as well as basics of the construction and the operation of geothermal energy systems. Contents of teaching are also heat transmission processes and basics of thermodynamics.

Geotechnical Engineering

Soil / Rock Mechanics

- soil and rock as multiphase medium
- soil stresses
- mechanical effects of water in soil
- material modeling of soil and rock
- theory of the elastic half space
- plasticity and shear strength of soils
- physical parameters of soil
- classification of soil and rock
- soil dynamics

Foundation / Rock / Tunnel Engineering

- retaining structures
- underpinning
- excavations
- foundations (raft, pile and combined pile-raft)
- dewatering
- banks and cuts
- slope stabilization
- soil improvement
- monitoring techniques
- observational method

Environmental Geotechnics

- capillarity
- multiphase flow in porous media
- geothermal energy
- groups of hazaerdous materials
- transport of hazaerdous materials
- rehabilitation of hazaerdous waste
- construction of landfills
- geosynthetics

Figure 3. Geotechnical curriculum at most German universities.

2.2 *PhD qualification (Dr.-Ing.)*

The most qualified students get the opportunity to work as research assistants after getting the degree “Dipl.-Ing.” or “Master of Science”. Then they are employed by the university and are fully payed. Besides their research work they have several duties e.g. in the field of education to fulfill. The program is completed with the writing of a dissertation and its defense.

With the beginning of the Bachelor and Master program some German universities also offer PhD-programs in special fields.

3 FURTHER BACHELOR AND MASTER PROGRAMS

3.1 *Environmental Engineering*

The Technische Universität Darmstadt and some more German universities offer by now a course of studies for environmental engineering. The contents of this Bachelor and Master course of studies are especially related to topics of the environment. The students gain the ability of designing, criticizing and operating environmental systems according to technical, economic and ecologic aspects. The evaluation of the economic and ecologic importance of the own action is also part of the education. Manufacturing of building materials and elements that can be recycled at the end of their service life and returned into the value-added chain or the reduction of environmental impacts during the entire lifecycle of technical and structural facilities which endanger the environment are further scope of duties of environmental engineers.

The education in the Bachelor of Environmental Sciences program starts with basic studies with focus on mathematics, mechanics, chemistry, biology and thermodynamics. During the last two terms of the Bachelor program the students have the opinion to choose one of the concentration programs “supply and return” or “environmental and land-use planning” The final degree is achieved with the preparation of a Bachelor thesis (duration on an average of about two months).

The studies of the Bachelor of Science program should be followed by the Master of Science program in environmental engineering.

Also in this course of studies geotechnics is an important part of the education. The contents that you can find in the category environmental geotechnics in Figure 3 are specified in the course of studies of environmental engineering. Also topics regarding geothermal energy and waste investigation and disposal are conveyed to the students.

3.2 *Facility Management*

Facility Management had developed to an interdisciplinary organization science, whose demand can yet only be covered by a few university graduates. On this account there exist currently efforts to provide an independent course of studies of facility management. In some universities there already exists an independent course of studies or the possibility to focus on facility management in the course of studies of civil engineering. Also in this course of studies there topics of geotechnics, in particular in the field of renewable energies are conveyed.

3.3 *Energy Engineering*

At the Technische Universität Darmstadt there is currently set-up the course of studies of energy engineering. After the completion of a Bachelor program in one of the 13 departments at the Technische Universität Darmstadt the Master program of energy engineering can be started. The organization of this course of studies is shown in Figure 4. In the first term the basics of natural and engineering sciences and humanities will be taught. Therefore a student of civil engineering chooses in the first term predominantly basics with the main focus on energy in the natural sciences, humanities and the other engineering disciplines. The first term is then followed by an individual focusing.

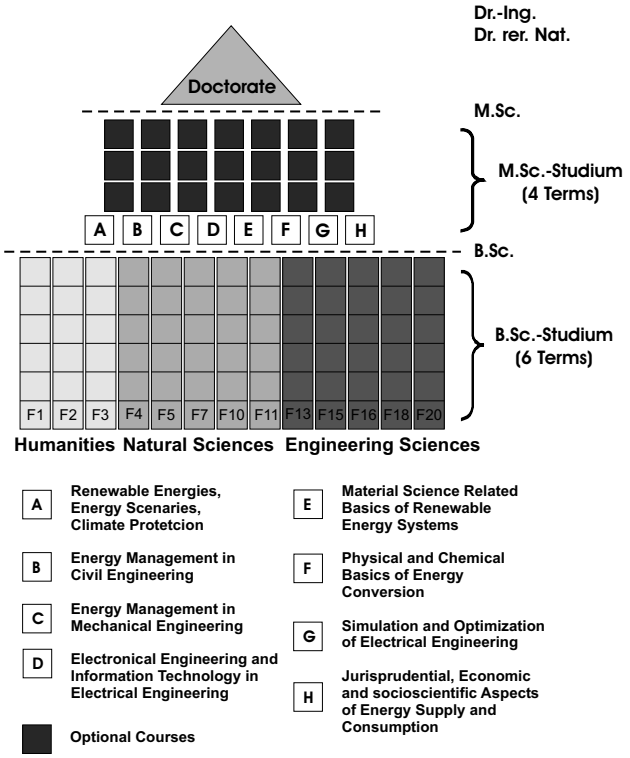

Figure 4. Energy Engineering at Technische Universität Darmstadt.

A PhD program completes the scientific qualification of the course of studies of an energy engineer. The PhD program ends with the hand-in of a dissertation and its defense. Depending on the individual main focus the degree can vary in "Dr.-Ing." (engineering) or "Dr. rer. nat." (natural sciences).

The geotechnical contents will also play an important role in the education of an energy engineer, in particular the topics of geothermal energy and heat and water transmission processes in the soil.

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