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Geotechnical engineering education in Israel

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ABSTRACT: Academic programs at the undergraduate level in civil engineering are presently offered at four academic institutions in Israel. Geotechnical engineering studies form part of these programs, but there are further requirements for qualification of the civil engineer to act as a geotechnical engineer. The study programs and requirements are discussed in this report.

1 INTRODUCTION

Academic undergraduate programs in civil engineering are presently being offered at four academic institutions in Israel – Technion – Israel Institute of Technology, Ben-Gurion University of the Negev, Sami Shamoon College of Engineering in Beer Sheba, and Ariel University Center of Samaria. These programs are aimed at providing the graduate with a BSc degree, and allowing him/her to be registered in one of the branches of civil engineering. In order to be licensed in his particular branch, the engineer must fulfill further requirements, which are presently being reconsidered. These include fulfilling specialized study programs and satisfying a minimum period of relevant professional experience (generally 3 years). Professional exams are also being considered.

In order to be recognized as a geotechnical engineer, the traditional, but not formal, requirement has been a higher degree in civil (geotechnical) engineering. This requirement will almost certainly be adopted in the licensing requirements presently being formalized by the Registrar of Engineers. At present, the only institution to offer graduate degrees in geotechnical engineering is the Technion. Consequently, almost all locally trained geotechnical engineers in the country have undertaken graduate study in geotechnical engineering at the Technion; these are complemented by immigrants with overseas graduate training.

2 UNDERGRADUATE STUDIES

2.1 *Typical geotechnical engineering study programs*

At the undergraduate level, geotechnical studies at most of the institutions form part of the general civil engineering study programs, and include compulsory courses in engineering geology, soil mechanics (or geomechanics), and soil engineering (or foundation engineering). Courses are run during a 14 week semester.

As an example of these programs, Ben-Gurion University includes the following three compulsory courses in its Structural Engineering program:

(i) Introduction to Geology: (2 contact hours/week) Rock forming minerals, rock classification and formation, geological structures, principles of stratigraphy, geological time, geological maps, ground water and hydrogeology, seismology.

(ii) Geomechanics: (2 lecture hours, 2 lab hours, 1 tutorial hour/week). Soil description and classification, soil compaction, flow and seepage, total and effective stresses in soil, settlement and consolidation, soil strength, lateral earth pressure, slope stability, retaining structures.

(iii) Foundation Engineering: (2 lecture hours, 1 tutorial hour/week). Site investigation, bearing capacity and settlement of shallow foundations, bearing capacity and settlement of deep foundations, foundations in sensitive soils.

2.2 *The Technion undergraduate program*

The most comprehensive program of courses in geotechnology is offered at the Technion. The

Technion offers several undergraduate study programs in Civil Engineering, including a general Civil Engineering program, and specialized programs in Structural Engineering, Building Management and Construction, Environmental Engineering, Agricultural Engineering and Transportation Engineering. Courses in Engineering Geology (2.5 contact hours/week) and Geomechanics (3 lecture hours, 1 lab hour, 1 tutorial hour/week) are compulsory for all Civil Engineering study programs. An additional course in Soil Engineering (3 lecture hours, 1 tutorial hour/week) is compulsory for the Structural Engineering and Building Management and Construction programs, and is elective for the others. Two additional courses, Field Investigations in Soil Engineering, and Introduction to Rock Mechanics, are offered as electives for all study programs, and are taken by students wishing to specialize in Geotechnolgy, within the framework of one of the Civil Engineering study programs. Students studying in the Structural Engineering program take the compulsory course Foundations, which deals with the structural aspects of foundation design. Finally, students wishing to specialize in geotechnolgy within the framework of any of the study programs, take a course in Flexible Pavements, and choose at least 3 courses from the list: Foundations, Advanced Hydrology of Groundwater, Applications of Finite Elements, Earth Dams, Drainage Engineering, and Introduction to Soil Chemistry. They also carry out a project in Geotechnolgy. The project runs over a semester, and may have a design or research flavor, occasionally even leading to publication. A recent example is a project in rock mechanics carried out by Nadav Bar-Ya'acov, under the supervision of Dr. Mark Talesnick. The project studied the mechanics and kinematics of a multiply jointed Voussoir beam, by testing small scale beams in the centrifuge. Fig. 1, showing the test set-up, is taken from a paper based on the project work (Talesnick et al., 2006); the upper figure is a schematic, while the lower is a digital image taken with the centrifuge model in flight at 40g.

2.3 Engineering Geology

The Department of Geological & Environmental Sciences at Ben-Gurion University offers a 3 year, BSc study track in Engineering Geology. The program combines studies from within the Dynamic Geology and Earth Structure track, with background courses provided by the Faculty of Engineering, emphasizing expertise in geological aspects of projects such as tunneling, subsurface storage, mine and quarry openings, rock slumps and slope stability, and substratum of construction for buildings, bridges and dams. In addition to general and geological courses, the program includes courses in Introduction to Geomechanics, Soil Engineering Laboratory, Intro-

duction to Geochemistry, Tunneling in Rock, Stability

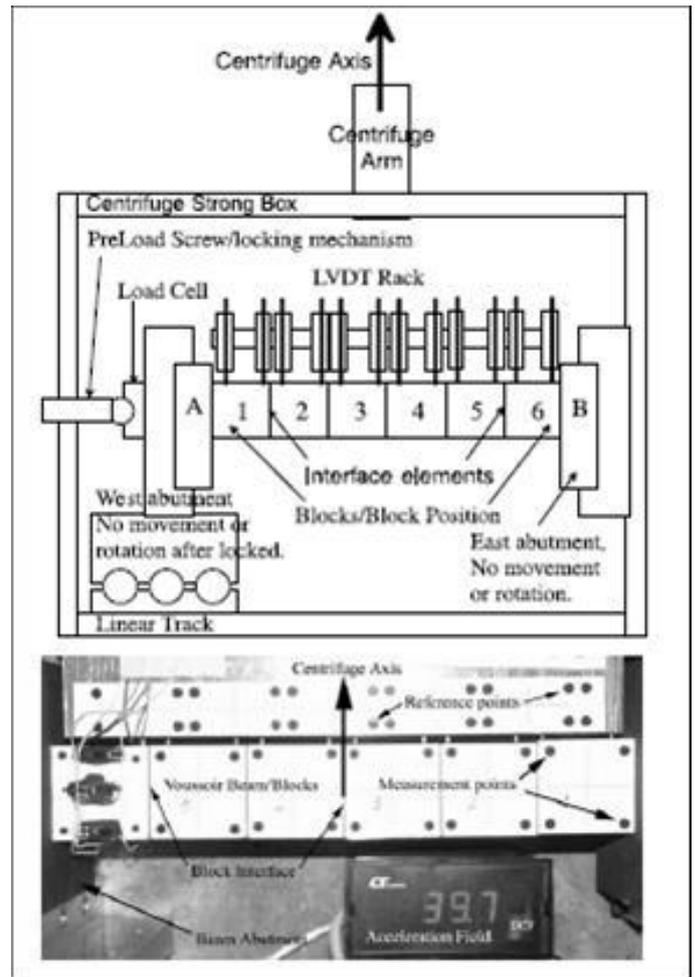


Figure 1. Test set-up used in undergraduate project

of Rock Slopes, Introduction to Geophysics, and Rock Mechanics Laboratory.

3 GRADUATE STUDIES

3.1 Masters degrees in Civil Engineering

The Technion is the only institute presently granting higher degrees in Civil Engineering. The Masters' degree in Civil Engineering (Geomechanics), requires accumulation of 36 credit points, according to three alternative options:

- (i) MSc, including a research thesis counting for 20 points and coursework counting for 16 points.
- (ii) MSc, including a final project counting for 12 points and coursework counting for 24 points.
- (iii) M.E., including an extended seminar counting for 5 points and coursework counting for 31 points.

One credit point corresponds to 1 lecture hour per week; most courses comprise one 2-hour lecture per week. All three programs are expected to extend over a period of two years.

The research carried out for option (i) is aimed at training the student in research techniques. The re-

search projects almost always result in professional publications in conferences and/or journals. The student presents his research at a public seminar, and his thesis is examined by an examining committee, followed by an oral examination. One example of a recent research project was that carried out by Meni Avishur under the author's supervision: "Physical Models for Soil-Pile Interaction under Seismic Loading." The project involved testing small scale models of driven piles in sand on a shaking table, using the hydraulic gradient approach to achieve similitude (Avishur et al., 2006). The model set-up used in these tests is shown in Fig. 2.



Figure 2. Test set-up Avishur's MSc research project

The final project carried out for option (ii) involves application of knowledge obtained during the MSc studies for comprehensive solution or analysis of a practical or research problem. The project is reported in a thesis, presented in a public seminar, and examined similarly to the research thesis. It often results in publication. One example of such a project is that carried by Alexander Bar under the joint supervision of the author and Prof. Sam Paikowsky from the University of Massachusetts, Lowell: "A study of the behavior of piles using a rheological model." This project involved extending a pre-developed rheological model (see Fig. 3) to analyze results from a large number of loading tests and back-calculate the parameters of the model.

The extended seminar involves a comprehensive literature review of a particular subject, performance of some analysis, and presentation of a seminar. An example of such a project is that carried out by Mellese Yimam under the author's supervision: "Ground response analysis in the Haifa region." The project involved reviewing the site response literature, preparing typical site profiles for six sites in the Haifa region on the basis of existing drilling logs,

and analyzing site effect using existing software for input from eight earthquakes recorded on rock in

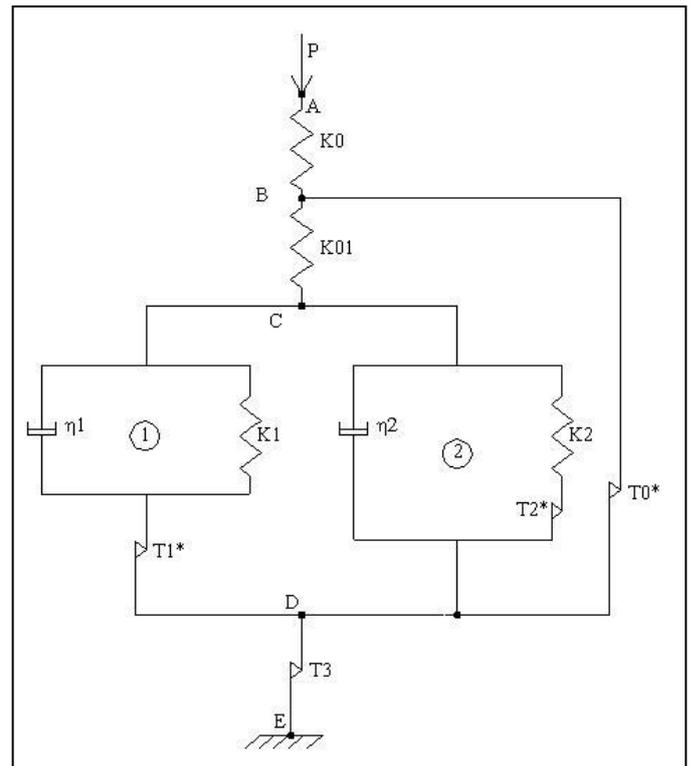


Figure 3. Rheological model used in Bar's project

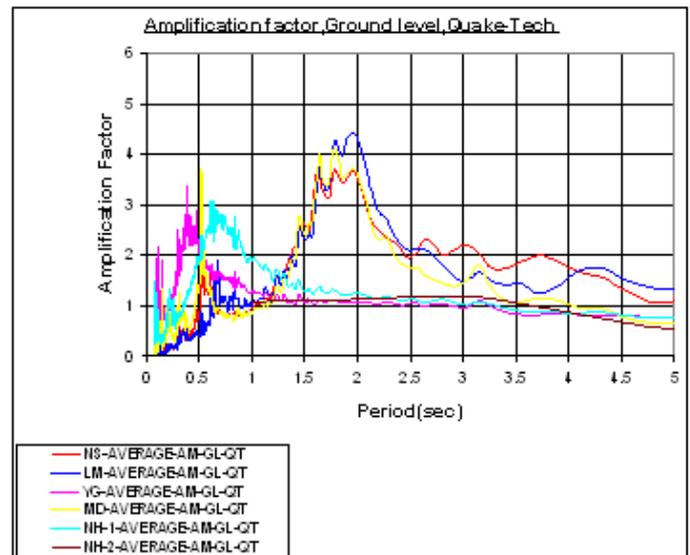


Figure 4. Site amplification factors, Yimam's extended seminar

California. Fig. 4 shows average site amplification spectra for the six sites.

The Masters' degree is the common geotechnical graduate degree in Israel, since it is effectively a requirement for becoming a geotechnical engineer. Full-time graduate students at the Technion always take the research track. In order to allow external students to work and study simultaneously, course work is concentrated during one full day a week, and

external students then complete their degrees by choosing one of the other two options.

The following is a list of graduate courses in geotechnology presently offered at the Technion:

(i) Introduction to Soil Dynamics

Review of fundamentals of vibration of systems with and without damping; wave propagation in soils; behaviour of soils under repeated and dynamic loading; response of foundations to vibration on the soil surface and within the soil; response of soils to earthquake loading.

(ii) Introduction to Rock Mechanics

The course introduces the fundamentals of rock mechanics while emphasizing practical rock engineering applications. Rock mechanics principles are used to explain selected geological and geotechnical phenomena. Rock mechanics principles are applied to the design of engineering structures.

(iii) Seepage and Slope Stability

Confined and unconfined flow under isotropic and anisotropic conditions; phreatic surface; piping; filter design; seepage forces; general principles of slope stability; failure of slopes under various conditions of seepage; methods of stability analysis including computer applications; residual strength and progressive failure; models and similitude; choice of soil parameters

(iv) Retaining Structures

Methods of design of sheet pile walls; anchors; slurry walls; types of wall supports and their influence on stress distribution on the wall; soil structure interaction; movements near excavations and retaining walls; overall stability; underground structures; choice of soil parameters.

(v) Advanced Soil Mechanics

Principle of effective stress in saturated and unsaturated soil; pore water pressure coefficients; stress space and stress paths; Rendulic and Henkel representations; soil strength criteria; Hvorslev strength theory; Rowe's stress dilatancy, and the Critical State approaches to soil behaviour; coefficient of earth pressure at rest; cyclic loading; swelling and collapsing soils. One-week laboratory at end of semester.

(vi) Geotechnical Earthquake Engineering

Background; seismology; characteristics of earthquakes; behavior of soil under cyclic loading; vertical shear wave propagation; site response; shallow and deep foundations and retaining walls during earth quakes; seismic slope stability.

(vii) Plasticity in Soil Mechanics

Definition of plasticity, present usage of plasticity concepts in soil mechanics, models and methods for analyzing soil mechanics problems; plastic behavior, stress-strain curves, yield functions, perfect plasticity and strain hardening, the flow rule, the normality requirements for stable materials; limit theorems and limit analysis; characteristics; critical state soil me-

chanics approach. Conventional methods of stability analysis (e.g. bearing capacity) in soil mechanics.

(viii) Constitutive Models in Geomechanics

Elementary tensor analysis, stresses and strains, equations of continuum mechanics; elasticity and hyperelasticity, hypoelasticity, quasilinear models, viscoelasticity, rheological models; plasticity: general considerations, classical soil plasticity models, non-associated plasticity, cap and critical state models; brittle materials.

(ix) Soil Improvement & Soil Stabilization

Classical elements of stability analysis (slopes and retaining walls); stabilization using piles, chemical stabilization (cement and lime), grouting; deep compaction, vertical drains; soil reinforcement, equivalent continuous models, limit equilibrium analysis and design.

(x) Foundations

Bearing capacity equations; correction factors related to soil compressibility; shallow foundations on layered soil; soil structure interaction, effect of structure rigidity on soil stress distribution, example of raft foundation; elastic approach to pile analysis based on Mindlin; wave equation analysis of driven piles; pile integrity testing; analysis of loading tests; foundation in swelling clays.

3.3 MSc in Engineering Geology – Ben-Gurion University

The Geological & Environmental Sciences Department at Ben-Gurion University offers an MSc program in Engineering Geology. The program includes courses on Rock Tunneling, and Rock Slope Stability (both common to undergraduate).

3.4 PhD studies

PhD studies are carried out in Geotechnology subjects at both the Technion and Ben-Gurion Universities.

4 REFERENCES

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