Challenges and responses in the geo-engineering education

P. Scharle
Széchenyi István University, Győr, Hungary

ABSTRACT: Structural engineers assess the geotechnical problems as difficult to model, complicated to calculate and full of crude approximations. In return, clear constraints hindering the practical use of advanced mechanical theories and computational software decrease the interest of geotechnicians in studying and applying them. In designing complex structures both sides restrict themselves in many cases to the exchange or prescription of some data given on interfaces. The paper presents an overview on differences either loosing their importance or remaining significant between these structural and geotechnical perspectives. Educational consequences related to the Bologna-process are discussed. Role of case studies and understanding of the observational method's importance are stressed. The paper concludes that geotechnical education should and could correspond to the challenges with more conscious and better structured curricula.

1 INTRODUCTION

Structural engineers have been assessing the geotechnical problems as difficult to model, complicated to calculate and full of crude approximations unacceptable at the level of structural engineering design. Indeed, for a long time, assumptions and estimations made necessarily with respect to the behaviour of the ground and the interactions between the structure and the surrounding soil were significant, and there was not too much reason in applying sophisticated theoretical and computational methods.

Even the body of geotechnical knowledge was questioned, not always without founds. Obviously, clear constraints hindering the practical use of advanced mechanical theories and computational software decreased the interest in studying and applying them. Consequently, structural and geotechnical engineers considered each others problems and methods with some suspicion. Having common lessons in designing complex structures their interaction often was restricted to the exchange or prescription of some data (forces, displacements or simple strength parameters) given on interfaces between *free-air* structures and foundations embedded into the soil.

Essential changes have challenged this practice during the last two decades. Everyday practice of the geotechnical engineering design and construction and its armoury became almost as sophisticated as that of the structural one. Whether the educational curricula correspond to this development?

The paper presents some considerations about the convergence and essential differences remaining between the structural and geotechnical problems. Some attention is focused on the Bologna-process, particularly on the selective content and differentiated presentation of body of knowledge at the BEng and MEng levels. Role of case studies and understanding of the observational method's importance are stressed.

2 TRADITIONAL DEFICIENCIES AND RECENT DEVELOPMENTS

Mechanics taught in the introductory semesters of civil engineering courses traditionally focuses on the models applied in the theory and design of structures. Well defined elementary models (trusses, frameworks, plates, shells etc) are discussed. Static and kinematic loads are taken as given data, boundary conditions (displacements or forces) are clearly defined. Linear and elastic material behaviour is assumed, a few words about granular materials, plasticity, irreversible state changes etc. are dropped.

Obviously, experienced geotechnicians are well aware the intrinsic problems making different their world of mechanics from that of the structural one. They know that

- the interaction between engineering structures and their soil surrounding is difficult to model;

- the extent of the surrounding (the boundary of the soil domain to be considered) itself is a matter of question;
- assumptions on linear, elastic material behaviour, isotropy, homogeneity are hardly acceptable;
- even the most simple constitutive parameters are difficult to obtain.

Having passed their sophomore exams, majors studying geotechnics arrive at and have to face this world. A small part of their prior knowledge can be applied here. Attention is shifted to the soil surrounding the engineering construction. Instead of one and two-dimensional problems plane and 3D problems appear. Most of the assumptions accepted in structural mechanics are commented as "crude approximation" or "valid only incrementally". Inelastic and nonlinear material behaviour is postulated, stresses and material characteristics depend strongly on the stress path of the state evolution. Model validation questions never mentioned in the previous elementary subjects arise.

With important exceptions, in many schools of geotechnical engineering, most of these aspects had been left up to the students either to think about or neglect them, treatment of the subject was *ab start* directed to the knowledge base of the geotechnical practice. The question *had I really need to learn structural mechanics to become a good geotechnician?* remained unanswered or was answered negatively.

For decades, the difference between the two worlds of applied mechanics might frustrated several professionals on both sides, but not really much was done to eliminate it. However, since the late eighties significant developments resulted in important changes.

- Interfaces between the *free air* and underground load bearing constructions have got more and more virtual. Airport terminals, shopping centers, public recreation facilities are the examples of complex structures where the functions of the upper and underground levels are impossible to differentiate with regard their position.
- Principles and rules applied in geotechnical codes have been harmonized with those of other engineering structures.
- Logistic and (natural or built) environmental aspects have high priority against the soil conditions when the loci of the constructions are determined.
- Advanced ground engineering technologies allow more slender, more flexible, more sophisticated geo-structures. Reinforced geo-composites come into general use.
- Interactive soil-structure design-construction procedures (such as the observational method) are available for significant and sensitive projects.
- Powerful computational hardware and software involving nonlinear, inelastic constitutive soil models with $10^4 \ldots 10^6$ kinematical degrees of freedom are at hand.

To cope with these developments and to prevent the depreciation of the geotechnical expertise and knowledge educators have to answer several questions, among them such as:

- should and could universities strengthen the mechanical background incorporated in the geotechnical education?
- how should the undergraduate (BEng) and graduate (MEng) curricula be separated and connected, respectively, in the linear education schemes?
- which "residual" specifics of mechanical knowledge have the geotechnicians to be catered with in their MEng courses?

3 EDUCATIONAL ISSUES

Results of the cognitive psychology and their application into the two-stage university education systems (among others, to the Bologna-model launched in the late nineties in the EU) and some aspects connected with the particular specialties of geotechnical body of knowledge help to find adequate answers to the questions raised above.

3.1 *Levels of knowledge and competence – analogies from the cognitive psychology*

Researchers exploring artificial intelligence have been for decades investigating the learning and experience building mechanisms that are typical for the learning and validation of a profession. They found that different levels of professional knowledge and preparation can be suitably described by the number and complexity of cognitive structures associated with each, as well as their organization. The system of these structures building on each other provides a good framework for a number of considerations regarding the mechanisms of cognition (Mérő, 2001).

Playing chess is the best example to understand the main ideas of this approach. Individuals with chess skills rated through tournaments all see the same board. Moves of the pieces are governed by strict and unambiguous rules. Number of possible positions is large but finite. The players, regardless of the extent of their experience or expertise, cannot influence these conditions.

In this sense chess is not a life-like game (for instance, real life games often involve the determination, even the modification of their rules). However, because of the high number and variety of possible positions, and since the knowledge, experience, mental state and even the physical condition of the players are greatly varied, one may distinguish characteristically different knowledge levels.

The *beginner* chess player is familiar with the rules and recognizes the possible moves in a given position. He is able to calculate the short-range consequences of his move, and whether it is to his advantage or detriment. He knows and uses a few dozen simple *schemes*.

An advanced, *second class* chess player is familiar with several low-degree-of-freedom positions (openings, endgames). The outcome of his matches in these simpler situations depends more on his obtained knowledge than on judging each and every position. The number *schemes* employed is a few hundred.

The *master candidate*, having played hundreds of matches and analyzed the games of others, is able to assess the middle game positions unfolding from openings. He is familiar with position improving options and recognizes similar or analogous precedents. The number of known and employed *schemes* is several thousand, a large percentage of which is complex.

The *grandmaster* also knows the strategic principles of manipulating games. Knowing hundreds of general patterns for various position options, he judges positions based on the opportunities of folding one into another. He formulates strategic plans that encompass entire games, utilizing several tens of thousand simpler or more complex *schemes* that are embedded in one another.

This classification, in an analogous sense, can be transferred to very different professional fields such as medicine, command of a language, architecture or law (Scharle, 2005). By and large, the master candidate level can be equated to a university degree.

In the natural sciences, a whole group of concepts parallel the chess concepts of position, analysis and move in terms of a problem. In this group belong, among others the

- observation, recognition, understanding, and anticipation of the phenomenon, situation, and process;
- recognition and description of tasks related to the progression;
- identification and analysis of the necessary and possible interventions;
- clarification and handling of expectable consequences;
- the determination and technical execution of intervention steps.

For the technical "jargon" *model* is probably the most expressive one among the common expressions analogous with the concept of scheme and are also used by professional languages. The concept defined this way is far from being a simplified (or even palpable) copy of an object, establishment or phenomenon, such as the scale model of a building or a small working model train set. It may consist of simple elements; it can be simple or complex. It also encompasses all mathematical, physical, technological and material-tectonic relationships that approximate reality and its behavior to an extent acceptable in the given circumstances. Application of the model may consist of simple steps, or form a closely related sequence of steps.

From this perspective *the essence of higher education in the engineering fields is the introduction of technical models of phenomena and processes*. The curriculum includes theories and relations that more or less describe reality, explores the validity and applicability of these models, and discusses the prerequisites, methods and steps of application. Simpler or more complex models can describe simpler or more complex phenomena. A well-educated professional is familiar with the most common and important phenomena, knows the relevant models, and is able to apply them to solve particular technical problems.

It is sensible to differentiate between levels of professional expertise from the perspective of their relationship to the inventory of models. Probably it is not possible to assign one "natural" classification. However, in order to answer the posed questions it seems practicable to accept a four level classification system (Scharle, 2008).

The significance of differentiating between these levels lies in their relationship to recognizing phenomena and processes, and to the models used for their understanding and intervention. Without striving for completeness, the levels can also be described by competencies as follows:

Apprentice – AEng

- Understands the main characteristics of models (of phenomena) conveyed by the bachelor or master.
- May participate in the application of models under guidance with simple steps.

Bachelor – BEng

- Recognizes frequently occurring phenomena.
- Is familiar with the profession's simpler models and their application.
- Correctly selects the models that can be employed for simple phenomena.
- Is able to involve the apprentice in model application by creating simple subtasks.
- Understands and executes the steps according to the model selected by the master.

Master – MEng

- Recognizes phenomena and correctly appraises their complexity.
- Knows the profession's inventory of models and the prerequisites and limitations of their applicability.
- Is aware of the limitations of her/his own competency.
- Is able to cooperate with masters of other fields in the solution of a complex problem.
- Is able to select the optimal model to solve a particular problem.
- Grasps the complete process of intervention, and is able to incorporate in particular steps the expertise

of the apprentice and bachelor according to their skills.
- Recognizes phenomena that require the further development of the model inventory, understands the way doctors think, and can utilize their recommendations.

Doctor – PhD
- Is able to identify and analyze complex phenomena.
- Knows the profession's model inventory and the limitations of their precision and applicability.
- Expands the range of validity of models, improves and develops methods for their application.
- Attaches models to new phenomena, and if necessary, supplements or creates new models.

The elements of all competencies may appear at all levels of education and there can be broad overlaps for a number of reasons. The educator's preparedness and perspective has an obvious role (many faculty members teach graduate students rather simple models extensively and with routine at the BEng level of expertise while a good grammar school teacher can make his interested pupils acquainted with pretty complex models using the master's perspective.

3.2 *Remarks related to the Bologna process*

Systems and frameworks of university education are multifarious. Among them, the Bologna-model of two stages (very similar to the Anglo-Saxon bachelor-master graduation regime) is evolving now in the EU (and in some other countries overseas, as well). Competencies identified before as connected with the bachelor and master levels seem to be usable when one wants to determine the content and outcome of these educational levels and curricula, respectively.

The content, purpose, and requirements of the outcome of education can also be defined through the consideration of relationship to model use. In this perspective the number of learned models and the quantity of acquired knowledge become less significant. Grades can be assigned to qualify the learning of the subject matter, and credits can be tied to the size of the taught inventory of models.

BEng graduates are prepared for the use of a relatively simple set of models accepted and "broken in" for the solution of already largely known, recurring problems. Perception and identification of the phenomena, selection and application of the adequate models assume MEng competence, as a rule. Moreover, interdisciplinary skill is the entrance to be gained for coping with the challenges in this field. Consequently, engineering education must offer all its courses at all levels consciously and openly stressing this compound demand.

4 PARTICULAR GEOTECHNICAL ASPECTS AND PERSPECTIVES

Convergence experienced between structural and geotechnical bodies of knowledge is reflected and will be accelerated in such points as:
- identification of the kinematic behaviour gets greater attention (Németh et al, 2006);
- more developed constitutive models with more reliable parameters are applied for the soil surrounding;
- interaction and co-operation of experts coming from their fields gets constrained with similar or integrated computational models and construction technologies;

In spite of this convergence there are some aspects wherein the two bodies are expected to remain different:
- model creation and structural completion is the focus of the geotechnical expertise while in structural design and construction the model selection and identification gets prior attention;.
- role of case histories in the higher geotechnical educational is more essential than in the structural engineering curricula (Scharle, 2008).

5 CONCLUSIONS

Spread of advanced engineering design and construction methods and restructuring of the competence levels challenge the higher education to improve its performance. Major curricula of geotechnics can respond the challenge with more conscious perspective and streamlined professional content.

REFERENCES

Mérő, L. 2001. *Habits of mind*, Springer, New York

Németh, G., P. Scharle, R. Szepesházi 2006. Innovative geotechnical structures – importance of the kinematic analysis, In J.Logar et al (eds.) *Active geotechnical design in infrastructure development*; Proc. XIII. Danube-European Conf. on Geotech. Eng., 657-660,

Scharle, P. 2005. Cognitive psychological structure of education and research in geotechnics, In Proc. of 16th ICSMGE, Osaka, 2157-2161

Scharle, P. 2008. Potential Role of Well-rounded Case Studies in Engineering Education. In Win Aung et.al (eds) *INNOVATIONS 2008, World Innovations in Engineering Education and Research*, INEER, Begell House Publishing (to appear)

ASCE 2007. *Civil Engineering Body of Knowledge for the 21st Century*, Report prepared by the Body of Knowledge Committee of the CAPPP

Educating the Engineer of 2020, 2005. *Adapting Engineering Education to the New Century*, The National Academy of Sciences, National Academies Press