LECTURE NOTES IN APPLIED AND COMPUTATIONAL MECHANICS VOL. 13

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Advanced Mathematical and Computational Geomechanics

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Preface

Geomechanics is the mechanics of geomaterials, i.e. soils and rocks, and deals with fascinating problems such as settlements (think of the Pisa tower), stability of excavations, tunnels and offshore platforms, landslides, earthquakes and liquefaction. In a long range it is conceivable that geomechanics will explain the deformation and fracture of the earth crust, as this is being analyzed by structural geology. Geomaterials, however, have an extremely complex mechanical behaviour: They can undergo very large deformations (cf. folding of large rock strata) exhibiting brittle or ductile behaviour, plastic flow, they can change their density upon shearing, they can interact with fluids entrapped within their pores, they can creep etc. The range of relevant scales in geometry and time is from nanometers to kilometers and from milliseconds to millions of years. On the top, geomaterials are rarely encountered in a virgin state, as they are the result of huge deformations, weathering and fracture. Research in Geomechanics is faced with problems which have — to an increasing degree — mathematical contents. To treat such problems engineers have to resort to their mathematical education which, as a rule, is rather limited and cannot be compared with the one of professional mathematicians. Recent advances of mathematics are, often, inaccessible to them.

In fact, the field of Geotechnical Engineering and Geomechanics is full of mathematical problems: We still do not possess a mathematical model that describes all aspects of soil behaviour, as revealed by experiments. The principal difficulties arise from the hysteretic behaviour. Even more difficult is the description of rock which, being a discontinuum cannot be described as a so-called simple material and must be endowed with a non-Euclidean internal geometric structure. On the top, the behaviour of rock depends on the time scale of observation. Whenever geomaterials have to be considered as mixtures of two or three phases (solid, liquid, gas), then the underlying balance and constitutive equations have to be formulated using complex averaging procedures, since experiments are often unfeasible. The underlying averaging procedures are mathematically very demanding, especially when we have to consider surface effects (as is the case for unsaturated soil). Wave propagation in such media poses additional mathematical difficulties. In view of the aforementioned problems the present mathematical models (i.e. constitutive models) are altogether simple approximations, although some of them exhibit a prohibitive complexity. Even though, the numerical solutions of boundary value problems of practical relevance encounter very soon limits, where the problems become ill-posed in such a way that many of our numerical tools break down. These mathematical problems are inherently related to peculiar pattern formations that are observed at the surface and in the interior of samples tested in the laboratory (see the article by J. Desrues in this volume).

Many mathematical applications in geotechnical problems can be drastically subsumed as follows: The problem is modeled by a system of linear equations that can be solved by computer. The encountered mathematical problems arise from several sources of non-linearity (geometric and/or material) and from the appearance of vanishing eigenvalues that signalizes non-uniqueness of solution. Engineers try to overcome such mathematical problems in a ‘pragmatic way’, which is in accordance to their education. Often, numerical tricks are applied that reside in an appropriate manipulation of numerical control parameters. As a result, the transparency and reliability of solutions is suffering. Therefore a deeper cooperation of mathematicians and engineers is urgently needed.

Another mathematical problem is how to express safety of geotechnical constructions? Engineers use the "factor of safety", which however is not a physical quantity (as e.g. temperature) and has many conceptual deficiencies. The probabilistic approach appears reasonable but is burdened by many difficulties.

In concluding I wish to mention that geotechnical engineering and geomechanics seeks to comply with Leonardo da Vinci saying that

> *Nessuna umana investigazione si può denominare vera scienza s' essa non passa per le matematiche dimonstrazioni*

i.e. research can only lead to true science if it is guided by mathematical methods.

Interdisciplinarity is a very fruitful but still a very cumbersome venture. When people having acquired different languages and approaches in a long series of years are brought together, they need a considerable amount of patience and enthusiasm, which is rarely encountered. All the more, I wish to cordially thank

- The participants and speakers of the three Euroconferences GeoMath (" Mathematical Methods in Geomechanics") that were held in 1-3 March 2000 (Innsbruck), 14-16 February 2001 (Innsbruck), 2-5 July 2002 (Horto/ Greece), out of which the present collection of contributions emanated.
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Dimitrios Kolymbas

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