

Dimitrios Kolymbas (Ed.)

Advanced Mathematical and Computational Geomechanics



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Lecture Notes in Applied and Computational Mechanics

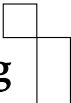
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Advanced Mathematical and Computational Geomechanics

Dimitrios Kolymbas (Editor)



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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 pecu-

liar 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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Innsbruck,
May 2003

Dimitrios Kolymbas

Contents

AUTHORS (alphabetical listing)	XIII
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Part I Material Modelling

On thermodynamic modeling and the role of the second law of thermodynamics in geophysics

<i>Krzysztof Wilmanski</i>	3
1 Introduction	3
2 Motivation	4
3 Two simple examples of evaluation of the second law	8
4 Simple and Biot-type poroelastic nonlinear models	16
5 Micro-macro-transitions for linear poroelastic materials	26
6 Concluding remarks	31
References	32

Some mathematics for the constitutive modelling of soils

<i>Guy T. Houlsby</i>	35
1 Potentials and the Legendre Transform	35
2 Functionals and Frechet derivatives	41
3 Convex Analysis	42
4 Conclusions	52
References	53

Elasticity in constitutive modeling of soils

<i>Alexander M. Puzrin</i>	55
1 Introduction	55
2 Elasticity in Geotechnical Engineering	56
3 Elasticity in Small Strain Behavior of Soils	58
4 Elasticity in Advanced Plasticity Theories	62
5 Elasticity in Thermomechanics	64

6	Elasticity in Micromechanics	67
7	Thermomechanics of Elasto-Plastic Coupling	71
8	Conclusions	73
	References	73

Experimental characterization of localized deformation in geomaterials

	<i>Jacques Desrues</i>	77
1	Introduction	77
2	Shear bands in field cases and laboratory tests	79
3	Localization in granular bodies	80
4	Localization in cohesive geomaterials	92
	References	102

Discontinuous character of rock masses: some open questions related to rock fracture mechanics and scale effects

	<i>Marta Castelli, Valeria Saetta, Claudio Scavia</i>	107
1	Introduction	107
2	Discontinuum methods: the Displacement Discontinuities Method ..	108
3	Conclusions and further developments	137
	Bibliography	137
	References	138

Similarity in soil and rock mechanics

	<i>Dimitrios Kolymbas</i>	141
1	Introduction	141
2	Scaling of size	142
3	Scaling of stress	152
4	Time scale	156
5	<i>II</i> -theorem and dimensional analysis	161
	References	163

Part II Modelling of Boundary Value Problems

Numerical predictions and reality

	<i>Ivo Herle</i>	167
1	Introduction	167
2	Predictions	167
3	Benchmarks	172
4	Making predictions	178
5	Concluding remarks	190
	References	191

Objective integration and geometric properties of hypoplasticity

Wolfgang Fellin, Alexander Ostermann 195

1 Introduction 195

2 Notions from continuum mechanics 196

3 Hypoplasticity 198

4 Objective time stepping 199

5 Geometric theory for element tests 202

6 Conclusions 209

References 209

Using constitutive models of the rate type in implicit finite-element calculations: error-controlled stress update and consistent tangent operator

Wolfgang Fellin, Alexander Ostermann 211

1 Introduction 211

2 A short introduction to hypoplasticity 212

3 A one-dimensional illustration of the consistent tangent operator for hypoplasticity 216

4 A general approach for consistent tangent operators 226

5 An illustrative academic example 229

6 Finite-element Example 234

7 Conclusions 236

References 237

Efficient and Reliable Nonlocal Damage Models

Antonio Huerta, Antonio Rodríguez-Ferran, Irene Morata 239

1 Introduction 239

2 Material Modelling 241

3 Numerical Aspects 245

4 Applications 254

5 Concluding Remarks 264

References 266

Regularized formulations of strain-softening plasticity

Milan Jirásek, Simon Rolshoven 269

1 Introduction 269

2 Problems with Objective Description of Strain Localization 270

3 Strain-Gradient Theories 276

4 Explicit Models with Gradients of Internal Variables 284

5 Implicit Gradient Models 286

6 Nonlocal Integral Models 292

7 Concluding Remarks 297

References 298

Fuzzy data in geotechnical models	
<i>Michael Oberguggenberger</i>	301
1 Introduction	301
2 Models of parameter variability	303
3 Computing with fuzzy sets	308
References	312

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