

Contents

Computational models for failure in cohesive-frictional materials with stochastically distributed imperfections

<i>M.A. Gutiérrez, R. de Borst</i>	1
1 Introduction.....	1
2 The finite element reliability method	2
2.1 Introduction to the reliability method	2
2.2 Discretisation of the material properties	4
2.3 Response as a function of the imperfections	4
2.4 Approximation of the probability of failure	6
2.5 Computation of the β -points	8
3 Computation of the mechanical transformation	9
3.1 Computation of the equilibrium path	9
3.2 Computation of the gradient of the equilibrium path	12
4 Numerical simulation	13
5 Conclusions	15
References	15

Modelling of localized damage and fracture in quasibrittle materials

<i>M. Jirásek</i>	17
1 Representation of localized deformation	17
1.1 Kinematic description	17
1.2 Constitutive models	19
1.3 Numerical approximations	21
1.4 Combined continuous-discontinuous description	22
2 Elements with embedded localization zones	23
2.1 Motivation	23
2.2 Low-order elements	25
2.3 Higher-order elements	26
2.4 Enriched elements	27
3 Concluding remarks	28
References	29

Microplane modelling and particle modelling of cohesive-frictional materials

<i>E. Kuhl, G.A. D’Addetta, M. Leukart, E. Ramm</i>	31
1 Motivation	31
2 Continuum-based microplane models	32
2.1 Microplane elasticity	34
2.2 Microplane elasto-plasticity	36
2.3 Example	37
3 Discrete particle models	38
3.1 Elastic particles	39
3.2 Elasto-plastic particles	41
4 Comparison	43

Short-term creep of shotcrete – thermochemoplastic material modelling and nonlinear analysis of a laboratory test and of a NATM excavation by the Finite Element Method

<i>M. Lechner, Ch. Hellmich, H.A. Mang</i>	47
1 Introduction and motivation for the investigation of creep in shotcrete .	47
2 Thermochemoplastic material model for shotcrete	48
2.1 State variables	48
2.2 Field equations.....	49
2.3 Heat conduction law	49
2.4 Constitutive equations	49
3 Algorithmic treatment of the incremental formulation for short-term creep	52
3.1 Discretization of the evolution law for short-term creep.....	52
3.2 Discretization of the incremental state equation for the stresses ..	53
3.3 Numerical example: creep test with two instants of loading	54
4 Re-analysis of a laboratory test	55
4.1 Modelling	55
4.2 Experimental determination of material properties.....	55
4.3 Results.....	57
5 Simulation of a tunnel driven according to the NATM	58

Thermo-poro-mechanics of rapid fault shearing

<i>I. Vardoulakis</i>	63
1 Introduction.....	63
2 Formulation	64
2.1 Mass balance	64
2.2 Energy balance	65
2.3 Momentum Balance	66
3 The Mathematical Model	68
4 Frictional shearing strain-rate softening	72

A view on the variational setting of micropolar continua

<i>P. Steinmann</i>	75
1 Introduction	75
2 Geometrically linear micropolar continua	76
2.1 Gradient type micropolar continuum	77
2.2 Cosserat type micropolar continuum	79
2.3 Mixed formulation gradient type case	80
2.4 Regularized mixed formulation gradient type case	81
3 Geometrically nonlinear micropolar continua	82
3.1 Mixed formulation gradient type case	83
3.2 Cosserat type micropolar continuum	84
3.3 Regularized formulation gradient type case	85
4 Conclusion	87

Macromodelling of softening in non-cohesive soils

<i>T. Marcher, P.A. Vermeer</i>	89
1 Introduction	89
2 Approach to friction softening	90
3 Drucker-Prager model with local softening	92
4 Necessity of regularization	94
5 Nonlocal DP-model	94
6 Internal length and numerical shear band thickness	96
7 Empirical shear band thicknesses	98
8 Softening scaling on h and l	100
9 Hardening soil model	102
10 HS-model with nonlocal softening	104
11 Geometrical Nonlinearity	106
12 Conclusions	107
References	108

An experimental investigation of the relationships between grain size distribution and shear banding in sand

<i>G. Viggiani, M. Küntz, J. Desrues</i>	111
1 Introduction	111
2 Experimental device and testing procedure	113
3 Tested sands	114
4 Experimental results	117
4.1 Monodisperse sands	119
4.2 Binary mixtures	123
5 Discussion	124
6 Conclusions	126
References	126

Micromechanics of the elastic behaviour of granular materials

<i>N.P. Kruyt, L. Rothenburg</i>	129
1 Introduction	129
2 Micromechanics	130
2.1 Branch and polygon vector	130
2.2 Stress, strain and work	132
2.3 Group averaging	132
2.4 Contact constitutive relation	133
3 Extremum principles	133
3.1 Statistical minimum potential energy theory	134
4 Discrete Element simulations	134
4.1 Particle size distribution	135
4.2 Assemblies	135
4.3 Discrete Element simulations	135
4.4 Averaging	136
5 Results from Discrete Element simulations	136
5.1 Geometry	137
5.2 Moduli	138
5.3 Relative displacements	138
5.4 Energy distribution	140
References	141

On sticky-sphere assemblies

<i>J. D. Goddard</i>	143
1 Cohesive materials	144
2 Conclusions and recommendations	147
References	147

Cohesive granular texture

<i>F. Radjai, I. Preechawuttipong, R. Peyroux</i>	149
1 Introduction	149
2 Simple contact laws with adhesion	150
3 Examples of observed behaviors	156
References	162

**Micro-mechanisms of deformation in granular materials:
experiments and numerical results**

<i>J. Lanier</i>	163
1 Experimental results	163
1.1 Experimental procedure	163
1.2 Displacements field of rods centers	164
1.3 Grains rotation	166
1.4 Rolling without sliding	166
1.5 Local deformation and shear band	167
2 Numerical simulations	168
2.1 Numerical simulations of biaxial tests	169

2.2	Local mechanisms of deformation	170
2.3	Numerical simulation of pull-out test	170
3	Conclusion	172
	References	172

Scaling properties of granular materials

<i>T. Pöschel, C. Salueña, T. Schwager</i>	173
1 Introduction	173
2 The normal force F^n	174
3 Scaling properties	175
4 Scaling large phenomena down to “lab-size” experiments	177
5 Bouncing ball	181
6 Consideration of the tangential force	181
7 Conclusion	183
References	183

Discrete and continuum modelling of granular materials

<i>H.-B. Mühlhaus, H. Sakaguchi, L. Moresi, M. Fahey</i>	185
1 Introduction	185
2 Formulation	186
2.1 Continuum model	186
2.2 Discrete element model	189
3 Lagrangian particle method	192
3.1 Lagrangian particles	193
3.2 <i>Numerical integration</i>	194
3.3 <i>Element matrices and particle properties</i>	195
3.4 <i>Particle splitting</i>	195
3.5 <i>Element inverse mapping</i>	197
4 Examples	198
4.1 DEM model simulating a triaxial compression test	198
4.2 DEM model of granular flow	199
4.3 LPM large deformation benchmark	200
4.4 LPM model of discharging silo	202
5 Concluding remarks	203
References	204

Difficulties and limitation of statistical homogenization in granular materials

<i>B. Cambou, Ph. Dubujet</i>	205
1 Definition of statistical homogenization in granular materials	205
2 Static averaging operator	206
3 Static localisation operator	207
3.1 General formulation	207
3.2 Analysis of the physical meanings of internal parameters μ and e_{ij}	207

3.3	Analysis of the capacity of different localisation operators from a numerical simulation	208
4	Kinematic averaging operator	210
5	Kinematic localisation operator	213
6	Conclusions	214
	References	214

From discontinuous models towards a continuum description

	<i>M. Lätzel, S. Luding, H.J. Herrmann</i>	215
1	Introduction	215
2	Model system and simulation	216
2.1	The Couette shear-cell setup	216
2.2	The discrete element model	217
3	From the micro- to a macro-description	218
3.1	Averaging strategy	219
3.2	Averaging formalism	219
4	Results on macroscopic scalar quantities	220
4.1	Volume fraction	220
4.2	Mass flux density	220
5	Macroscopic tensorial quantities	221
5.1	Fabric tensor	221
5.2	Stress tensor	223
5.3	Elastic deformation gradient	223
5.4	Material properties	223
6	Rotational degrees of freedom	225
7	Summary and conclusion	228
	References	229

From solids to granulates – Discrete element simulations of fracture and fragmentation processes in geomaterials

	<i>G.A. D'Addetta, F. Kun, E. Ramm, H.J. Herrmann</i>	231
1	Introduction	231
2	Description of the model	233
2.1	Granularity	234
2.2	Elastic behaviour of the solid	235
2.3	Breaking of the solid	238
2.4	Stress calculation	239
3	Simulation results	239
3.1	Quasi-static loading scenarios	240
3.2	Dynamic fragmentation of solids	249
4	Conclusions	256
	References	257

**Microscopic modelling of granular materials
taking into account particle rotations**

<i>W. Ehlers, S. Diebels, T. Michelitsch</i>	259
1 Introduction	259
2 Kinematics	261
3 Equations of motion	262
4 Contact laws	264
5 Numerical aspects	268
6 Simulation examples and results	269
7 Conclusions	272
References	273

**Microstructured materials: local constitutive equation
with internal lenght, theoretical and numerical studies**

<i>R. Chambon, T. Matsushima, D. Caillerie</i>	275
1 Introduction	275
2 A general theory for continua with microstructure	276
2.1 Kinematic description of a continuum with microstructure	276
2.2 The internal virtual work	276
2.3 The external virtual work	276
2.4 The balance equations and the boundary conditions	277
3 Microstructured continuum with kinematic constraint: Second gradient models	277
3.1 Equations of a second gradient model	277
3.2 Local elasto-plastic second gradient models	278
4 An application of local elasto-plastic second gradient model	279
4.1 The problem to be solved	279
4.2 Partial solutions	280
4.3 Patch conditions and full solutions	282
4.4 Discussion	283
5 Equations with Lagrange multipliers	284
6 Equations for the iterative procedure	284
7 Finite Element Method	286
7.1 Shape functions	286
7.2 Element stiffness matrix	287
7.3 Element residual terms	288
7.4 Global matrices	289
8 Applications: two dimensional elasto-plastic constitutive relation	289
9 Conclusions	291
References	291

**Damage in a composite material under combined mechanical
and hygral load**

<i>H. Sadouki, F. H. Wittmann</i>	293
1 Introduction	293

2	Generation of numerical concrete	294
3	Drying process and self-desiccation	295
3.1	Basic elements and equations governing the processes	295
3.2	Material parameters	296
3.3	An example of simulation of drying	298
4	Endogenous and drying shrinkage	299
4.1	General concept	299
4.2	Shrinkage in normal and high performance concrete.....	300
5	Conclusions	306

Continuous and Discontinuous Modelling of
Cohesive-Frictional Materials

Vermeer, P.A.; Diebels, S.; Ehlers, W.; Herrmann, H.J.;

Luding, S.; Ramm, E. (Eds.)

2001, XIV, 310 p., Hardcover

ISBN: 978-3-540-41525-1