

Table of Contents

Introduction	xiii
Chapter 1. Debris Flows	1
Christophe ANCEY	
1.1. Introduction	1
1.2. Typology of torrential flows	2
1.2.1. Watershed as a complex physical system	2
1.2.2. Types of transport	3
1.3. Initiation, motion and effects of debris flows	6
1.3.1. Initiation	6
1.3.2. Motion	7
1.3.3. Deposition and effects	11
1.4. Modeling debris flows	12
1.4.1. Debris flow classification and rheological behavior	12
1.4.2. Rheometry	13
1.4.3. Application: sheet flows	19
1.4.4. Slow motion	22
1.4.5. Fast motion	24
1.5. Bibliography	30
Chapter 2. Snow Avalanches	39
Christophe ANCEY	
2.1. Introduction	39
2.1.1. A physical picture of avalanches	40
2.1.2. Avalanche release	40
2.1.3. Avalanche motion	43
2.2. Modeling avalanches	45
2.2.1. Statistical methods	45

2.2.2. Fluid-mechanics approach (avalanche-dynamics models)	47
2.2.3. Simple models.	49
2.2.4. Intermediate models (depth-averaged models).	60
2.2.5. Three-dimensional computational models	64
2.2.6. Small-scale models.	64
2.3. Bibliography	65
Chapter 3. Instability of Soil Masses	73
Laurent VULLIET	
3.1. Introduction	73
3.2. Slowly moving slopes.	75
3.2.1. Principal characteristics	75
3.2.2. Determination of the laws of creep <i>in situ</i>	76
3.2.3. Modeling of the mass	78
3.3. Limit state analysis	78
3.3.1. Mohr-Coulomb criterion.	78
3.3.2. Infinitely long slope	80
3.3.3. Methods of slices	82
3.3.4. Finite-elements method	83
3.4. Case of non-saturated masses	84
3.4.1. Problem.	84
3.4.2. Types of modeling	85
3.4.3. Three-phase modeling	88
3.4.4. Applications	88
3.5. Conclusion and prospects	90
3.6. Bibliography	91
Chapter 4. Instability of Rock Masses	93
François DESCOEUDRES	
4.1. Introduction	93
4.2. Cliff stability and toppling	94
4.2.1. Sliding	95
4.2.2. Toppling	97
4.3. Contact-impact	99
4.3.1. General remarks.	99
4.3.2. Impact at the surface of the terrain.	99
4.4. Flight trajectory	101
4.5. Sliding and rolling.	103
4.5.1. Sliding	103
4.5.2. Rolling	104
4.5.3. Rolling with sliding	106
4.6. Impact on an embankment (safety embankment).	107
4.6.1. Poncelet's empirical formula	107

4.6.2. Method of elastic shocks	107
4.6.3. Dynamic punching	109
4.7. Capacity of the protective structures	111
4.7.1. Elastoplastic model	111
4.7.2. Capacity of the various types of structures	112
4.8. Conclusion	114
4.9. Bibliography	114
Chapter 5. Subsidence Phenomena	117
Bernhard SCHREFLER and Luciano SIMONI	
5.1. Subsidence caused by water withdrawal	117
5.1.1. Introduction	117
5.1.2. The mathematical model	118
5.1.3. Possible numerical problems	121
5.1.4. Case studies: comparison between observed behavior and the predictions of numerical models	123
5.1.5. Second study case: the subsidence of Albano Terme	134
5.2. Artificially-induced land uplift	141
5.3. Conclusions	146
5.4. Bibliography	147
Chapter 6. Soil Collapse due to Water Infiltration	149
Yu-Jun CUI and Pierre DELAGE	
6.1. Introduction	149
6.2. The loess in Northern France	151
6.2.1. The collapse of loess	154
6.2.2. Geotechnical characterization of the samples	155
6.2.3. Collapse behavior of the loess	159
6.2.4. Evaluation of various collapsibility criteria	163
6.3. Conclusion	165
6.4. Bibliography	167
Chapter 7. Subsidence Induced by Fossil Fuel Extraction	171
Christian SCHROEDER, Yu-Jun CUI and Bernhard SCHREFLER	
7.1. Introduction	171
7.2. Subsidence due to coal extraction	172
7.3. Recap of the basic Barcelona model	176
7.4. Subsidence due to oil exploitation	179
7.4.1. Deposition of chalk in sea water (OA)	183
7.4.2. Migration of oil in chalk (AB)	183
7.4.3. Migration of oil in chalk after clay deposition (BC)	184
7.4.4. Depletion (CDE)	184

7.4.5. Waterflooding (EF)	184
7.5. Subsidence due to the exploitation of gas reservoirs	185
7.6. Acknowledgements	197
7.7. Bibliography	197
Chapter 8. Deterioration of Stone in Monuments	201
Véronique VERGÈS-BELMIN	
8.1. Introduction	201
8.2. Intrinsic degradation factors	202
8.2.1. Mineralogical composition	202
8.2.2. Hydric and hygic properties	204
8.2.3. Water: water vapor transfer properties	205
8.2.4. Thermal properties	208
8.2.5. Mechanical properties	210
8.2.6. Hardness	212
8.3. Extrinsic degradation factors	214
8.3.1. Frost	214
8.3.2. Salts	215
8.3.3. Atmospheric pollution	228
8.3.4. Biological colonization	235
8.3.5. Patinas	237
8.4. Acknowledgements	240
8.5. Bibliography	240
Chapter 9. The Physics of Water Transfer in Stone	247
Jean-Paul LAURENT	
9.1. General concepts and terminology	247
9.1.1. Water intake	247
9.1.2. Drying	249
9.1.3. Difficulties in assessing the global water cycle in a monument	250
9.2. Water in stones: capillarity	250
9.2.1. Water content	250
9.2.2. Water–stone interaction	253
9.2.3. Capillary condensation	257
9.2.4. Retention curves	258
9.3. Modeling water transfer in stone	263
9.3.1. Darcy’s law of permeability	263
9.3.2. Different expressions of the liquid water flux	265
9.3.3. Water transfer in unsaturated porous materials	266
9.3.4. Infiltration theory	268
9.3.5. Vapor water transfers: coupling	271
9.4. Bibliography	271

Chapter 10. Experimental Techniques for Characterizing Alterations 275
 Claude BRUNJAIL, Guy BASTIAN, Grégoire CHÉNÉ and Véronique VERGÈS-BELMIN.
 Updated by Philippe BROMBLET

10.1. Laboratory and <i>in situ</i> testing	275
10.1.1. Microscopy and physicochemical analyses	279
10.1.2. Porosimetry tests	290
10.1.3. Mechanical tests	292
10.2. Hydric and thermal transfers: specific techniques	296
10.2.1. Problems	296
10.2.2. Independent variables	298
10.2.3. Phenomenologic parameters and related parameters	299
10.3. Bibliography	303

Chapter 11. Case Studies 313
 Jean GODIN, Claude BRUNJAIL, Véronique VERGÈS-BELMIN and Ann BOURGÈS

11.1. Notre-Dame-la-Grande Church in Poitiers, <i>in situ</i> study	313
11.1.1. Preliminary diagnostic	313
11.1.2. Follow-up of water contents after restoration.	314
11.2. Research on earthen plaster stabilized with bitumen and polychrome decoration: Navrongo cathedral, North Ghana	321
11.2.1. Introduction	321
11.2.2. Materials and methods	323
11.2.3. Results	324
11.2.4. Conclusion	329
11.3. Bibliography	330

Chapter 12. The Nature and Survey of Soil Pollution 333
 Abdelmalek BOUAZZA, Pierre DELAGE and Michel WOJNAROWICZ

12.1. Introduction	333
12.2. The nature of soil pollution.	334
12.3. The survey of contaminated sites	339
12.3.1. Sampling strategy	341
12.3.2. Geotechnical site investigation methods.	345
12.3.3. Geophysical methods	355
12.4. Conclusions	356
12.5. Bibliography	357

Chapter 13. Retention and Transfer of Soluble Chemical Pollutants: Mechanisms and Numerical Modeling 361
 Robert CHARLIER and Jean-Pol RADU

13.1. Introduction	361
13.2. Ideal pollutant transport in an ideal continuous medium	362

13.2.1. Flow equations	362
13.2.2. Transport laws: advection	363
13.2.3. Transport laws: dispersion	363
13.2.4. Transport laws: diffusion	365
13.2.5. Transport laws: synthesis	365
13.3. Pollutant retention phenomena	366
13.4. Balance equations	369
13.5. Numerical modeling of transport by advection	371
13.6. Finite elements modeling of the problem with advection and diffusion	372
13.6.1. Galerkin's method	372
13.6.2. One-dimensional case	373
13.6.3. Petrov-Galerkin method	376
13.6.4. Transient problems	378
13.6.5. Generalization in two and three dimensions	379
13.6.6. The method of characteristics and Galerkin's method	379
13.7. Examples and applications	380
13.7.1. Pollutant pulse one-dimensional propagation	380
13.7.2. Two-dimensional reference problem	382
13.7.3. Determination of a protection zone around a pumping well	383
13.7.4. <i>In situ</i> tracer test	386
13.8. Conclusions	388
13.9. Acknowledgments	388
13.10. Bibliography	389
13.11. Notations table	390
Chapter 14. Retention and Transfer of Pollution by Hydrocarbons: Mechanisms and Numerical Modeling	393
Bernhard SCHREFLER and Pierre DELAGE	
14.1. Introduction	393
14.2. Mechanisms	393
14.3. Numerical modeling	398
14.3.1. The physical model	399
14.3.2. The mathematical model	402
14.3.3. The numerical model and its solution	404
14.3.4. Pollutant transported by water or air in the soil pores	406
14.3.5. Examples	407
14.4. Conclusion	415
14.5. Bibliography	416

Chapter 15. Methods of Soil Environmental Remediation	419
Abdelmalek BOUAZZA, Michel WOJNAROWICZ and Mario MANASSERO	
15.1. Introduction	419
15.2. Pollution control techniques	420
15.3. Active containment <i>in situ</i>	423
15.3.1. Pump and treat	423
15.3.2. Reactive barriers (low permeability)	423
15.4. Passive treatment <i>in situ</i>	425
15.4.1. Natural attenuation	425
15.4.2. Reactive barriers (high permeability)	427
15.5. Active treatment <i>in situ</i>	429
15.5.1. Immobilization (inertage) technologies	429
15.5.2. Extraction technologies	435
15.5.3. Incineration	449
15.5.4. Excavation/put in discharge	450
15.5.5. Biological breakdown <i>in situ</i>	450
15.5.6. Phytoremediation	453
15.6. Conclusions	453
15.7. Bibliography	454
Chapter 16. Liners for Waste Containment Facilities	459
Abdelmalek BOUAZZA, Michel WOJNAROWICZ and Mario MANASSERO	
16.1. Introduction	459
16.2. Types of lining systems and definition of basic components	462
16.3. Mass balance of the contaminants	464
16.4. Functions, performance and modeling	465
16.5. Environmental impact evaluation (risk analysis)	466
16.6. Bottom barriers	469
16.6.1. Hydraulic conductivity at the field scale	470
16.6.2. Compatibility	475
16.6.3. Desiccation	476
16.6.4. Sorption parameters	477
16.6.5. Dispersion-diffusion parameters	478
16.7. Equivalence of liner systems	481
16.8. Composite liners	491
16.9. Conclusions	501
16.10. Bibliography	502
List of Authors	509
Index	513