

Index

Page numbers in *italics* denote figures. Page numbers in **bold** denote tables. Letter 'b' after a page number indicates a text box.

- alignment
 - route corridors 72, 76, 83–84, 87, 89, 94, 135, 136, 139–141
 - selection 70, **72**, 73, 103, 145, 180
- alluvial fans **90**, **104**, 136
- alluvium **16**
- aluminium oxide precipitation 15, **16**, 18
- anchors, rock slope stabilization **197**, 198, 199, 200
- andosols **16**, 19
- Antecedent Precipitation Index 27
- apron
 - culvert outlet 257, 260, 264
 - gabion 185, 186, 187, 240, 266
- aquifer 200
- ash, volcanic, andosols 19, 23
- ASTER data **80**, **83**, **86**
- Atterberg limit testing **122**, 123, 170
- augering 118
- automatic classification 75, 77, 78, **82**, 85
- avalanches **35**, 36, 41, 44, 45, 46
- Average Annual Daily Traffic (AADT) 1, 137, 140b, 141
 - Halsema Highway 47
 - management prioritization 279
- Azerbaijan, benched cut slope profile 155b

- back analysis 166, 168, 170–171, 184, 185, 191b
- back scarp 33, 173, 179b
- backfill 184, 185, 186
 - free-draining 185, 186
 - granular 232, 233
 - non-cohesive 218
 - retaining walls 185, 186, 219, 221, 226, 227
- bamboo **252**, **256**
- band ratios 78
- barriers, rockfall protection **197**, 203
- basalt
 - columnar 46, 49, 50
 - talus 24
- bearing capacity 64, 121, 175, 180, 217–218, 219, 220
- bearing pressure **211**, 215, 219, 220, **222**
 - allowable 224–225
- benched cut slope profile 152–154, 155b, 231, 235
- bending moments 216
- bending restraint **211**
- berms 152, 158, **197**, 200
- Bhutan
 - above-road slope failure stabilization 179b
 - satellite imagery 77–78, **84**
- bill of quantities 8, 11, 12
- bio-engineering
 - erosion control 246–257
 - maintenance **271**, 272
 - root systems 247–248, 249
 - site preparation 250, 256
 - techniques 250, **251–253**, 254, **256**
 - timing 257
 - slope protection 12, 13, 14
 - spoil dumps 161, 162
- black cotton soils 19, 23, 49, 176

- blasting 152–153, 154
- blinding layer 222, 223, 225, 263
- block sampling 121
- bolts, rock slope stabilization **197**, 198, 199
- boreholes
 - ground investigation 117, 118–121
 - inclinometers 130b
- borrow areas 117
- bridges 137, 145, 148
- brush layering **251**, 254, 255, **256**
- buffer zone, rockfall protection 203
- bulking 158
- buttresses, rock slope stabilization **197**, 200, 202, 228

- calcium carbonate precipitation 15, 21
- camber 142, 176
- carriageway 47, 49
 - design 139–143
 - erosion 265
 - landslides 47, 49
 - slope failure 62, 65b
 - width 140b, **141**
- cascades
 - drystone 258, 259
 - gabion 258, 259, 260, 261
 - masonry 259
- case-hardening 15, 18, 19, 149
- castellations 227–228
- catch ditches 196, **197**, 203
 - rockfall protection, maintenance **271**
- catch fences 196, **197**, 203, 206
- catch pit 177
- catch walls 196, **197**, 203, 204, 205, 206
- cementation *see* precipitation, cementing compounds
- channel linings 259–260, 262
- checkdams 238, 239
 - gabion 257, 258
 - plants **252**, 255, **256**, 258
- Chenab Bridge, India, rock slope stability analysis 194–195b
- Chi Chi earthquake (1999), Taiwan, debris flows 40
- China *see* Sichuan earthquake (2008)
- chunam, erosion control 246, **271**
- chute 186, 239, 241, 242
- cleavage, adverse 25, 26, 29, 30
- climate zones 2, 3, 4
- cohesion 168, **172**, 192b, **217**
- colluvium **16**, 19–20, 22, 24, 25
 - slope failure 38
- compaction 64, **147**, 156, 158, 178, 221, **222**
 - backfill 215, 218, 219, 227
 - tests **122**, 123, 227
- concrete
 - precast 212
 - reinforced 180, 200, 203
 - drains 233, 241
 - pipes 264
 - retaining walls 181, 203, 205, 209–210, **211**, 212, 213, 228

- concrete (*Continued*)
 - revetments 243, 244, 245
 - scour buttress 265
 - walls 181, 185, 205, 209, 210, **211**, 213, 215, 219, 224, 225, 228
- conditioning factors **31**, **83**, 91, 273
- construction
 - costs 8, 145, 146b, 161
 - labour-based **11**, 12, 14
 - local resource-based 12, 13, 14
 - observational method 11
 - practices 158
 - quality control 226–228
 - retaining walls 223–228
 - risk management 61–62
 - site investigation 67, **68**, **69**, 70
 - desk studies 71–99
 - field mapping 103–115
- contracts 8, **10–11**, 11–12, 108
 - cost-based **10**, 12
 - design and build 11–12
 - directly-employed labour **11**, 12
 - performance-based 282b, 283
 - price-based remeasurement 8, **10**, 11–12
 - rates-only **10**, 12
 - term 283
- cores 131b
 - recovery 121, 123, 124, 156b
- corestones 17, 18, 20, 21, 25
- costs
 - construction, 145, 146b 161
 - excavation 146b, 182
 - maintenance 62b, 178
 - target **10**, 12
- crib walls 210, **211**, 212, 213, 214
- cross-section, choice of 145, 146b, **147**, **148**
- crossfall 142, 153
- culverts **238**, 239, 240–242
 - inlet blockage 242
 - outlet scour 242
 - erosion control 260, 262, 263, 264, 265
- curve radius 139–140
- cut and fill **97**, **98**, 141, 158, 243, 246
 - balanced **104**, 137, 145, **148**
- cut slope angle 145–146, 148–150
 - analytical approach 152, **153**
 - empirical approach 150–152
 - knowledge-based design 146, 148–150
- cut slope failure 173–176
- cut slope profile 152–156
 - benched 152–154, 155b, 231, 235
 - compound 154, 156, 157b
 - continuous 154
- cuttings, plant **251**, 254, **256**
- debris, removal of 173
- debris flow 20, **35**, 36, 38, 40–41, 43, 44
- debris slides 31–32, **34**
- decision making 7, 59
- deep cuts 117, 152
- defects liability period 11
- deforestation 26, **31**
- density, testing **122**, 158, 226
- dentition, rock slope stabilization **197**, 200, 203
- design
 - detailed 7, 8, **68**, **69**, 145
 - engineering 67, 70
 - preliminary 7, 8, **9**, **68**, **69**, 108
- design and build contract 11–12
- design charts 169
- design parameters 108
- design speed 140b, **141**
- design stage 7–8, **9**, 71
 - road drainage 235–237
- design standards 171
 - drainage 237, **238**
- desk studies 67, **68**, **69**, 70–99
- Digital Elevation Model (DEM) 77, **82**, **86**, 127
- DInSAR 127
- discharge
 - drains 223, 232, 238–241, 243, 259
 - rainwater 142–143, 153
- discontinuities, rock slope failure 189–193
- discrete element analysis 194b
- dowels
 - rock slope stabilization 196, **197**, 198, 199
 - see also* soil nails
- drainage
 - earthworks 153, 154, 156, 159, 162, 163
 - grips 222, 223
 - retaining walls 221–223
 - road 235–242
 - design criteria 235–237, **238**
 - field inspection 237–238
 - rock slope stabilization 176, 179, 186, 187, **197**, 198, 200
 - slope 231–242
 - maintenance **271**
 - and slope failure 176–179, 187
- drainage patterns 67, **69**, **74**, **83**, 179, 237
- drains
 - backfill 222, 223, 227
 - bench 153, **234**
 - berm 231, **234**, 236
 - counterfort 232, 233, **234**
 - cut-off 231, 232, 233, **234**, 235b
 - herringbone 176, 177, 185, 186, 232, 233, **234**, 236
 - interceptor 222, 223, 232, **234**
 - roadside and turnouts **148**, 154, 156, 158, 163, 222, 238–240
 - side 223, 238, 239
 - sub-horizontal 185, 200, 232, 233, **234**, 236
 - sub-surface 179b, 180, 186, 237
 - surface 186, 222, 231, 232, 233, 235
 - toe 232, 235
- drill and blast 152
- drilling
 - ground investigation 117, 120–121
 - rotary 120–121
- driving forces **31**, 168, 173, **175**, 183, 228
- dry season 158, **253**
 - construction 187
 - maintenance 273, 274, 275, 278, **279**, 280
 - soil development 18, 19, 88, 89
- duricrusts **16**, 18, 20, 21b
- dynamic cone penetrometer 224, 225

- earth pressures 209, **211**, 215, 217, **219**
- earthquake loading **34**, 194b, 206
- earthquakes 27, 32b, 56
- earthworks 145–163
 - balance 158–159
 - choice of cross-section 145, 146b, **147**, **148**
 - cut slope angle design 145–146, 148–150
 - cut slope profile choice 152–156
 - fill slopes 156, 158
 - spoil disposal 159–163
- effective stress 40, **122**, 165, 176
- embankments 19, 158, 168
 - fill 236
 - river 263
 - testing **122**, 123
 - turnout 239
- engineering geology **61**, **62**, 70, **104**, **106**
 - assessment 260, 262
 - mapping **69**, **72**, 76, **106**, **112**, 113–115
- envelope curves 151, 152
- equilibrium calculations, retaining walls 215–218
- erosion
 - side drains 238–239, 240
 - slopes 48, 52
- erosion control 243–267
 - bio-engineering 246–257
 - culvert outlets 260, 262, 263, 264
 - local resources 13, 14
 - revetments 243–244, 245
 - stream erosion 257–260
 - surface coverings 244–246, **252–253**, **271**
 - chunam 246
 - mattresses and matting 246
 - shotcrete 245–246
 - toe erosion 260, 262–263
- Ethiopia
 - above-road slope failure stabilization 179–181
 - construction costs 8
 - cut slope angle 156b
 - engineering geology mapping **112**, 115
 - landslide mapping **111**, 115
 - reference condition mapping **103**, **104**, 108
 - retaining walls 219, **220**, **221**
 - rockfalls 49
 - route corridor and alignment selection **141**, 143–144
 - slope failure 48–49, 52
 - terrain model 84, 86, 87
 - vertisols 19
 - see also* Hirna-Kulubi road
- excavation 154, 156b, 158
 - costs 146b, 182
 - design 17–18b
 - drains 235, 237
 - fill 145
 - hillside 64
 - retaining walls 219, **222**, 223–224, 225–226
 - and slope failure 168, 172, 173, **174**, 182
 - spoil 243
 - techniques **104**, 152
 - trench 254
- existing roads
 - choice of cross-section 145
 - GIS **97**
 - maintenance 162
 - risk management 62–65
 - site investigation 67–70
 - spoil 162–163
 - stabilization 65
- fabric, rock 15–19, 25, **31**, 149
- failure, regressive 173, 182, **184**
- false colour composite imagery 77, 85
- fascines **251**, **254**, **256**
- faults 19
- feasibility studies 7, **9**
 - Laos study 60–62
- ferricrete **16**, 89
 - see also* duricrusts
- field inspection
 - drainage 237–238
 - slope movement monitoring 129
- field investigation 67, **68**, **69**
- field mapping **68**, 103–115
- fill
 - free-draining **211**, 212, 218, 219, 222, 223, 227, 232
 - granular 176, **177**, 232, 233
 - reinforced 145, **147**, 158, **175**, 203, 209, **210**, **211**, 215, 219, **220**
 - in road sections 145, 146b, **147**, **148**
 - see also* backfill; rock fill
- fill slopes 156, 158
- filter fabric **186**, 212, 221–223, 232, 233, 246, **261**, 263, **266**
- financial risk 282b, 283
- Finite Element Limit Analysis (FELA) 169, 191, 193
- Finite Element Method (FEM) 169
- first-time failure 31, 59, 166, 170, 172
- flood levels 236, 238, 241, 266
 - Trisuli River 64b
- flooding 70
 - risk of 87, 89
 - river 64b, 184, 258, 262, 265
 - Typhoon Ondoy 54b
 - vegetation cover 250
- flow velocity 238, **242**, 260, **261**, 262
- flows **35**, 40–41
- folding 22, 26, 27, 28
- foliation, and slope failure 25, 30
- foundations
 - erosion control 258, 259, 263
 - retaining walls **211**, 219, 223, 224
 - undermining 48, 60, 64
- free-drainage 15
 - backfill 185, **186**
 - fill **211**, 212, 218, 219, 222, 223, 227, 232
 - rock fill 17b
- friction 168, 170
 - interparticle 15, 18b, 20, 21, 22b, 25
 - retaining walls 217–218, **219**
- friction angle 25, 33, 38, **122**, 152, 168, 189, 191–192b, 217, 221
- full cut **104**, 145, 146b, **147**, **148**, 180, **184**
- full fill 145, 146b, **147**, **148**
- gabions 175, 176, 185–187, **204**, 210–212, 220
 - cascades 258, 259, **260**, **261**
 - checkdams 257, 258
 - quality control 227–228

- geofabric 177, 179, 186
see also geotextiles
- Geographical Information Systems (GIS) 75, **97**, 98–99
- geogrids 209, 210, **211**, 215, **252**
- Geological Strength Index 152, 193
- geomorphology
 mapping **68**, **69**, **72**, 76, 109, 110, 114, 115, 120b, 131b, 177
 processes 67, 82
- geophysics, investigative techniques 123–124
- geotechnical assessment 67, 70, 171
- geotechnical failure 218
- geotechnical parameters 117, **119**
- geotechnical problems 137
- geotextiles, erosion control 246, **253**
- gneiss
 slope failure 25
 weathering 21
- Google Earth 82
- gradient 139, 140b
- grass 248–250, **251**, **252**, 255, **256**
- gravel, graded 223
- gravity structures 196, 200, 209, 212
- gravity walls 209, **211**, 217, 223, 224
- ground conditions 15
 assessment 10, 67, **69**, 84, 94, 103
 uncertain 82, 84, 117, 123, 136–137, 139, 171
 unforeseen **69**, 108
- ground investigation 67, **68**, **69**, 117–125
 methods 118–124
 scope 117–118
 supervision 124–125
- ground models 156, 165, 167, 170
- ground truthing **68**
- groundwater observation **119**, 124
- groynes 262–263
- gullying 146, 235b, 243
- gypsum precipitation 15
- hairpin stacks 114, 115, 135, 137, 139, 143, 239–240, 259
- Halsema Highway, Philippines
 below-road slope failure stabilization 182b
 impact of landslides 47, 49, 53, 54
 use of inclinometers 131b
- Himalayas
 debris flows 40–41
 landslides 54–56
 metamorphic rock 25
- Hirna-Kulubi Road, Ethiopia
 cut slope failure stabilization 175–176
 landslide damage 65b
 trial pitting 120b
- Hong Kong
 above-road slope failure stabilization 179
 articulated surface drain 232, 236
 engineering geology mapping 115
 landslide threshold 27
 saprolites 19
 slope movement monitoring 127, 128b
- hydraulic design 260, 262
- hydraulic gradient 223
- hydro-seeding **253**
- hydrostatic pressure 222
- igneous rocks 25
- IKONOS imagery 78, **80**, 82, **84**, 85, **86**
- imagery
 airborne 73, 75, **86**
 satellite **69**, 75, 77–78, **80–81**, 82, **83**, **84**, 85, **86**
- incision 38
 drains 238, 239
 stream erosion 44, 257, 260
- inclinometers 130b, 131b
- infinite slope analysis 169
- InSAR **83**, 127
- interferometry
 differential radar (DInSAR) 127
 synthetic aperture radar (InSAR) **83**, 127
- iron oxide precipitation 15, **16**, 18
- irrigation 48, **74**, 231, 237, 270, 273
- IRS data 78, **80**, **81**, **84**
- joints
 adverse 37, 204, **277**
 infill 25, 31
 relict **16**, 19, 22b, 23, 31, 165, 166
- Karakoram, debris flow 40
- kinematic feasibility **31**, 189
- labour, directly employed **11**, 12, 14
- land acquisition 7, **98**, 156, 157b
- land elements 86
- land facets 86, 87, **90**, **91**
- land systems 86, 87, 90
- land use, and route corridor selection 137, **138**
- Landsat data 75, 77, 78, **84**, 85
- landslides
 aerial photography 71–73, **74**
 causes 25, 27, **31**
 deep-seated 118, **175**, 183, 184, 194–196, **197**, 200, 206
 displacement 46
 engineering geological mapping 115
 hazard 4–6, 59–60
 mapping 93, 105, 106, **107**, 108–113
 impact on road network 47–56
 commercial costs 47
 engineering costs 47
 social costs 48
 management, literature 1–2
 mechanisms 25–56
 probability 59, 60, 89, 96, 172, 275, **279**, 280–281
 reinstatement engineering 70
 risk 59–61
 management 61–65
 runoff 105, 110
 stabilization of existing roads 65
 susceptibility 59, 281
 mapping 89, 91, 93–96, 98, 105–107, 108–113
 triggering factors 28, **31**, **83**, 91, 172
 types 27, 31–46
 vulnerability 59, 60, 90, 96
see also slides
- Laos
 cut slope angle 156b
 entire slope, failure stabilization 183, 184
 fill slope, failure stabilization 178

- landslide impact 47–48
- landslide risk assessment 60, 61
- national standards **141**
- slope management feasibility 60–62
- laser scanning, terrestrial 129
- laterite 15
- latosols 15, **16**
- launched nails 212
- leaching 15, **16**, 243
- levees, debris flow 40, 43
- LiDAR airborne imagery **69**, 73, 75, 79, **86**, 127
- limestone, failure mechanisms 37, 56
- limit equilibrium 169–70, 189–90, 191b, 193
- limit state 171, 216
- line-of-sight, slope movement monitoring 129
- low-cost roads
 - aerial photography 73
 - satellite imagery 75, 77, 78, **82**, **83**
 - site investigation **68**
 - slope stability analysis 166
- low-volume roads, geometric standards 139, 140b, 141
- lump sum contracts **10**, 11
- lumped factors of safety 171–172, 218–219

- Mackintosh probe 121
- Main Central Thrust, Himalayas, landslides 56
- maintenance **68**, **69**, 70, 269, 283
 - costs 62b, 178
 - dry season 273, 274, 275, 278, **279**, 280
 - emergency 62b, 270, 273, 275, 278, 280–283
 - existing roads 73, 163
 - mountain roads 59, 62b, 65
 - preventative 273, 275, 278, **279**, 280–283
 - procurement 282–283
 - remedial 270, 273, 275, **277**, 278, **281**, 282–283
 - routine 270, **272**, 273, 275
- manganese precipitation 15
- mapping
 - engineering geology **69**, **72**, 76, **106**, 112, 113–115
 - geomorphological **68**, **69**, **72**, 76, 109, 110, 114, 115, 120b, 131b, 177
 - landslides 89, 93–96, 98, 105–107, 108–113
 - reference conditions 103, **104**, 108
 - topographical **72**
 - satellite data 82
- masonry
 - cascades 259
 - checkdams 258
 - composite 209, **211**, 213, 223
 - dry stone 13, 14, 209, **211**, 227
 - retaining walls 173, 175, 176, 178, 180, 209, 210, **211**, 212, 213, 220
 - quality control 227
 - revetments 243, 244
- mass haul diagram 158–159
- matting, erosion control 246
- mattresses, erosion control 246
- meanders
 - erosion control 263, 266–267
 - migration 136
- mesh
 - restraining, rock slope stabilization **197**, 198, 200
 - rockfall protection **197**, 201, 202–203, 204
 - see also* netting
- metamorphism
 - slope materials 22, 25
 - slope stability 26, 28
- method statement **9**
- Microsoft Virtual Earth 82
- modelling, numerical, rock slopes 190–193
- moment of failure 166, 170
- moments 168, 217, 218, **219**
- monitoring, slope movement 127–132
- monuments, landslide monitoring 129
- mudflow 20, **35**, 38, 40, 43
- mudslides 32, **34**, 38
- Murree Formation, Pakistan, landslides 54, 55

- nails *see* launched nails; soil nails
- Naubise-Mugling road, Nepal
 - entire slope failure stabilization 184–187
 - flood damage 64b
- Nepal
 - Arun III hydropower access road 7
 - bioengineering 248
 - cut-off drains 235b
 - entire slope failure stabilization 184–187
 - flood damage 263, 265
 - maximum gradient 139
 - national standards **141**
 - rock slope failure 206–207
 - satellite imagery 77–78, **84**, 85
 - slope movement monitoring 127, 128b
 - spoil management 161
 - stereo aerial photography 72, 76, 77, 78
 - terrain classification 89, 92
 - see also* Naubise-Mugling road
- netting 180, 202–203, 206, 246, **252**
 - see also* mesh
- new roads
 - cross section 145
 - GIS **97**
 - risk management 61, 62
 - site investigation 67, **68**, **69**, 71–99, 103–115
 - spoil 159–162

- observational method 11
- overhangs 173, 196, **197**, 200
- overturning, retaining structures 180, 217–218, 219, 220, **222**

- palisades **251**, 254, 255, **256**
- Pamir Mountains
 - hydropower access road, construction cost 8
 - rock avalanche 44, 46
- Papua New Guinea
 - landslide hazard mapping 105, 106, 109–110, 113
 - LiDAR mapping 73, 79
 - rock avalanche 44, 45
- partial factors of safety 172, 218–219
- passive forces 216, 217–219
- pattern dowels 198
- permeability
 - cascades 259
 - clay soil 124
 - geotextiles 246

- permeability (*Continued*)
 - and plant growth 247
 - soil 165, 179, 232, 237
 - variable **31**, 32
- Philippines *see* Halsema Highway
- photography, aerial 71–73, 75b
 - digital 73
 - stereo 71, 72–73, **74**, 76, 79
 - mapping landslides 71–72, 127, 128b
- phyllite 25, 26, 30
- piezometers, groundwater observation **119**, 124
- planar failure 31–34, 36–39, 41, 168–169, 189–190, 191b, 193
- planting
 - materials 249
 - schemes 243, 245, **253**
 - techniques 250, **251–253**, 255, **256**
 - timing 257
- plants 247–250
 - maintenance **271**, 272
 - selection of species 256–257
- plasticity **16**, 18b, **122**, 176
- pore pressure 32b, 40, **122**, 149, 150, 165–166, 168, 169–170, 172, 176, 190
- porosity, volcanic ash 19
- pre-split blasting 152–153, **197**
- pre-stressed ground anchors **197**, 198–200
- precipitation, cementing compounds 15, 18, 21b
- pressure
 - active 216, **217**
 - passive 216, 218
 - see also* pore pressure; water pressure
- probability, landslide 59, 60, 89, 96, 172, 275, **279**, 280–281
- probing 121
- procurement
 - contractor 8
 - maintenance 282–283
 - project phase 7, 8, **9**, **11**
- project phasing 7–8, **9**
- propagation 248, 249
- Q-System 193
- rainfall, and landslide triggering 27, 60
- raingauge 132
- ravelling 28, **104**, 105, 195, 196, 200, 245
- realignment **119**, **174**, 178, 181, 182–183, 186, 206–207
- reconnaissance surveys 103
- reference conditions, mapping 11, **68**, **69**, 103, **104**, 108
- regrading 173, 178, 183, 196, **197**, 250
- regression, landslide 173, 181, 182b, 183
- reinforced concrete *see* concrete, reinforced
- reinforced fill *see* fill, reinforced
- relict discontinuities 19, 22b
 - and slope failure 23, 25, 31
- relict joints **16**, 19, 22b, 23, 31, 165, 166
- relict structures 18b, 19, **31**
- remeasurement contracts **10**, 11
- remote sensing 70
 - airborne 75, 79
 - slope movement monitoring 127, 129
- resisting forces 25, 168, 173, **175**, 218, 228
- resources, local 12, 13, 14
- retaining structures 209–228
 - backfill 219, 221
 - construction 145, 223–228
 - design 215–219
 - drainage 221–223
 - types 209–215
 - see also* walls, retaining
- revetments 198, 243–244, 245
- Rift Valley, Ethiopia, landslides 49, 52
- rip-rap 185, 186, 257, 258, 260, 261, 262, 263, 266
- risk assessment 59–61, 275, 280
 - quantitative 91
- risk management 61–65, 275, 280
- risk matrix 61
- river crossings, route corridor selection 135–136, 137
- river training 262
- road authority 11, 47, 141, 182, 207, 283
- rock
 - sampling and testing 121, 123
 - types and structures 22, 25, 26, 30
 - weathering, grade classification 15, 17–18b, 19, 20
- rock fill 17b, 145, 146b, **211**
- rock flow **35**
- rock head surface 166, 169, 185
 - planar failure 31, 39
- rock mass 25, 28, **31**, 152, 153, 189–198, 200, 203, 220, 224
 - classification 193, **195**
 - deformation 33, **35**
 - discontinuities 33, **34**
- rock quality, gabions 227
- rock reinforcement 191b, 196, **197**, 200
- rock slopes
 - maintenance **271**
 - stabilization 165, 189–207
- rock strength 189, 191b
- rockfalls **35**, 36, 37, 44, 46, 47, 49
 - road protection 196, **197**, 202–206
 - trajectory 202, 203
- rockslides 32–33, **34**, 40
- rooting 246–249, **253**
- roots, and erosion control 247–250, **251–252**
- roughness
 - discontinuity **153**
 - hydraulic 241
 - joint 189, 192b, 194
- route corridors
 - alignment 135, 136, 139–141
 - feasibility study, West Africa 87, 88, 89
 - identification and selection 135–139
 - alternatives 137, 139
 - land use 137
 - river crossings 135–136, 137
 - slope stability 136–137, **138**, 139
 - topography 135, 136
- runoff 142–143, 153, **154**, 156, 162, 176, 178
 - drainage 231, 232, 237
 - erosion 225, 245, 246, **251–252**, 260
 - slope stability **31**, 32b, **34**, **35**, 48, 52
- runout *see* landslides, runout
- rural roads 77, 140b

- sampling
 - disturbed 118, 121, **122**, 123
 - undisturbed 118, 120–121, **122**, 123, 152, 170
- sandstone, rockfall 48
- saprolite 18–19
- SAR data **83**
- satellite imagery **69**, 75, 77–78, **80–81**, 82, **83**, **84**, 85, **86**
 - multi-spectral **81**, **83**
- scaling, rock slope stability **197**, 200, 202
- schist, slope failure 25, 26
- scour 27, 33
 - culvert outlets 242, 260, 262, 263, 264, 265
 - drains 238, 239, 240, 241, 242
 - river 27, 33
- scour checks 258, 266
- sediment
 - deposition 87
 - load 257, 261
 - transport 136, 238, 241, 242, 260
 - see also* soil types, transported
 - variability 154, 156b
- seeding **251**, **252**, **253**, **256**
- seepage 32, **106**, **107**, 149, 150, **151**, 176, 184, 203
 - drains 232, **234**
 - erosion 231, 235b, 243, 250, **256**, 259, 261
 - retaining structures 210, 222, 223
- seismic load 218
- seismic refraction 124
- seismicity **97**, **138**
 - and instability 28, 32b, 43, 54, 56, 172, 182b
- sensitivity analysis 170
- settlement, differential 175, 209, 219, 220
- shale 25, 26
- shear key 156, 158, 177, 219
- shear resistance 219, 220
- shear strength 17b, 23, 38, 121–123, 152, 165, 170, **172**, 193
 - backfill 218, 219
 - role of vegetation 247
- shear surface 47, 117, 120b, **122**, 123, 167
- shear vane 123
- shelters, rockfall protection **197**, 205, 206
- shotcrete
 - erosion control 245–246
 - rock slope stabilization **197**, 198, 200, 213, 214, **271**
- shrink-swell cycle **16**, 19
- shrubs 248, 250, 256
- Sichuan earthquake (2008), China, avalanches 45, 56
- side-long ground 181, 240
- silica precipitation 15
- site investigation 67–70
 - desk studies 71–99
 - field mapping 103–115
- slate 25, 26
- slickensides 30, 33, 39
- slides 31–40, **34**
 - circular failures **34**, 36, 37–40, 42, 55, 168–169
 - planar failures 31–34, 36–39, 41, 168–169, 189–190, 191b, 193
 - rotational 39, 42, 55
 - wedge failures 33, **34**, 36, 37, 193
 - see also* landslides
- sliding resistance 189, 219, **222**, 225
- slip indicators 130b
- slip surfaces 168–169
- slope analysis, infinite 169
- slope angle 145–152, 157b, 158
 - limiting 180
- slope erosion 48, 52
- slope failure
 - deep-seated 118, **175**, 183–184, 194–196, **197**, 200, 206, 217
 - equilibrium techniques 189, 190
 - kinematics 189, 191–192b
 - numerical modelling 190–193
 - stabilization
 - above-road slopes **174**, 178–181
 - below-road slopes **174**, 181–183
 - cut slopes 173–176
 - entire slopes **174**, 183–187
 - fill slopes **174**, 176–178
- slope instability
 - categories 5–6
 - risk report **276**, **277**, 280
- slope inventories 113, 274
- slope management 269–283
 - inspection 273, 274–275
 - maintenance 269–273
 - emergency 273
 - preventative 273
 - prioritization 279–282
 - emergency 281–282
 - preventative **276**, **277**, **278**, 280–281
 - procurement 282–283
 - remedial 273
 - routine 270, **272**, 273
 - planning 269–270
 - proactive 269
 - risk management 275, 279
- slope movement monitoring **69**, 127–132
 - interpretation of data 132
 - measurement 129–131
 - methods 127–131
- slope profiles 150, 152, 154, 156, **166**, 167, 170, 250
- slope protection, local resources 12, 13, 14
- slope stability
 - analysis 166, 168–171
 - assessment 166
 - conditioning factors **31**
 - controlling factors **31**
 - engineering geology mapping 112, 113–115
 - metamorphism 26
 - route corridor selection 136–137, **138**, 139
 - see also* rock slopes, stabilization; soil slopes, stabilization
- smectite **16**, 19
- soil
 - cohesive 169, 171
 - granular 119, 121, **122**, 168, 224
 - moisture 27, **122**, 123, 250, **251**, **253**
 - non-cohesive 170, **251**
 - sampling and testing 121–123
- soil nails 179, 180, 210, **211**, 212–215
 - launched 212
- soil profiles **119**, 123, 166
- soil slopes
 - stability analysis 166, 168–171
 - stability assessment 166

- soil slopes (*Continued*)
 - stabilization 165–187
 - factors of safety 171–172
 - ground model 165–166, 167
- soil types 15–22
 - in situ* weathered 15–19
 - transported **16**, 19–22, 24
 - tropical residual 15, **16**, 21b
 - weathering grades 15, 17–18b, 19, 20, 21b
- soil/rock interface 157b
- specifications 7, **9**, 11
 - backfill 227
 - catch fences 203
 - design 7, **9**
 - gabions 227
 - ground anchors 198, 200
 - laboratory testing 125
 - mortar 227
 - soil nails 215
 - spoil 161, 163
- spoil, disposal of 159–163
- SPOT data 77, 78, **80**, **83**, **84**, 85, **86**
- Sri Lanka
 - engineering geology mapping *114*, 115
 - hill road widening, construction costs 8
- stability analysis
 - rock slopes 189–193, 194–195b
 - discontinuity-controlled
 - multiple closely-spaced *190*, 193
 - persistent 189–193
 - slope design 191–192b
 - soil slopes 166, 168–171
 - back analysis 170
 - basic concepts 166, 168–170
 - first-time failure analysis 170
 - forward analysis 170–171
 - strength parameters 170
- stability assessment 166, 189–193, 194b
- stabilization
 - rock slopes 165, 189–207
 - drainage 200
 - labour-intensive **197**
 - management 193, 195
 - modes of failure 193, 195, *196*
 - reinforcement and support 195–200
 - removal of rock (scaling) 200, 202
 - road protection 202–206
 - stability assessment 189–193, 194b
 - soil slopes 165–187
 - above-road slope failure **174**, 178–181
 - below-road slope failure **174**, 181–183
 - cut slope failure 173–176
 - entire slope failure **174**, 183–187
 - fill slope failure **174**, 176–178
 - stability analysis 166, 168–171
- standard details, retaining walls 218
- Standard Penetration Tests 121, 123
- standards
 - design 7, **9**, 141, 171
 - engineering 117, 124
 - geometric, low-volume roads 139, 140b, 141
 - safety 171
 - slope safety factors 171–172
- stereonets 189, 191–192b
- stiffness 15, 17–18b, 21b
 - binding 212
 - mortar 227
- stilling basins 260, 263, 264
- stone pitching **253**, **256**
- stream erosion 257–260
- strength parameters, soil 152, **166**, 170, 217
- suction, soil 15, 22, 27, 165, 247
- superelevation 142–143
- supervision
 - construction 8
 - ground investigation 108, 124–125
- surcharge 218, **219**, 237
- surcharge loads *167*, 168, 219
- surface coverings 244–246, **252–253**, **271**
- susceptibility 59, 281
 - mapping 89, 91, 93–96, 98, *105–107*, 108–113
- Taiwan, debris flow 40
- Tajikistan, engineering geology mapping *113*, 115
- talus 19–20, *24*, 46, *50*
- taluvium **16**, 19–20, 22, *24*
 - above-road slope failure stabilization 180, 226
 - debris slides 31, 38
- tectonic stress, and rock slides 33
- tension crack measurement 130
- terrain classification 67, **68**, **69**, 84, 86–87, 89, 90, 92, 108
 - see also* automatic classification
- terrain evaluation 67, **68**, **69**
- terrain modelling **69**, 82–84, 86, 87, 108
- testing, soils and rock
 - in situ* 123
 - laboratory **122**, 123
- thermal imaging 75, **81**, **83**
 - see also* ASTER data
- toe erosion 40, *42*, 258, 260, 262–263
- toe support *see* berms
- topography 67, **69**
 - route corridor selection 135, *136*
 - see also* mapping, topographical
- toppling **35**, *36*, *37*, 44, 46, *49*
 - rock slope failure *193*, *196*
- topsoil *17*, *26*, 156, 162
- total geology approach 84
- traffic
 - delay 62b, 145, 206, 228
 - loads *167*, 168, 218
 - safety 140b, 141, 142, 158, 203, 206
 - volume 140b, 141
- trees 250, **252**, **256**
- trial pits and trenches 118, **119**, 120b
- triggering factors 28, **31**, **83**, 91, 172, 273
- truncheon cuttings **251**, 255, **256**
- tuff 23, *24*, *30*, 48–49, **104**, *110*, 120b, 176, *177*
- tunnels, rockfall protection **197**, *205*, 206
- turnouts 238–240
- Typhoon Igme (2004), Halsema Highway 131b
- Typhoon Ondoy (2009), Halsema Highway 54b
- underpinning **197**, 200, 260

- valley floor routes 135, 136, **138**
- Value of Time (VoT) 47
- vegetation *see* bio-engineering
- Vehicle Operating Costs (VOCs) 47
- vertisols **16**, 19, 23, 49
- Vietnam, national standards **141**
- virtual back 209
- void ratio 21b
- vulnerability 59, 60, 90, 96, 275, **279**, 280–281, 282
- walls
 - retaining 13, 14, 145, 147, 209–228
 - above-road slope failure stabilization 180
 - active pressure 216, **217**
 - backfill and drainage 219, 221–223
 - below-road slope failure stabilization 182b
 - concrete 181, 203, 205, 209–210, **211**, 212, 213, 228
 - construction 145, 223–228
 - excavation stability 225–226
 - existing wall stability 228
 - foundations 223–225
 - height 223
 - length 225
 - quality control 226–228
 - crib 210, **211**, 212, 213, 214
 - cross-section 219, **222**
 - cut slope failure stabilization 175
 - design 215–219
 - entire slope failure stabilization 185–187
 - equilibrium calculations 215–218
 - excavation 219, **222**, 223–224, 225–226
 - factors of safety 218–219
 - gabions 175, 176, 185–187, 210–212, 220
 - masonry 175, 176, 178, 180, 209, **211**, 212, 213, 220
 - passive pressure 216, 218
 - seismic loads 218
 - surcharges 218
 - water pressure 218
 - tied-back, rock slope stabilization **197**, 200, 201
 - wash boring 121
 - water content **35**, 172
 - water pressure 124, 168, 190, **197**, 200, **217**, 218, **219**, 244
 - uplift 219
 - see also* pore pressure
 - water table 65, 124, **138**, 170, 172, **175**, 176
 - perched **34**, 146, 165, 166, **175**
 - wattle fences **253**, 255
 - weathering
 - grades 15, 17–18b, 19, 20, 21b, 165, 166, 179b, 182, 220, 245
 - soils 15–22
 - weathering profile 88, **104**, **107**, 108, 121, 156, 165, 193
 - wedge failure 33, 36, 37, 191b, 193
 - weepholes 200, 221, **271**
 - wet season
 - bio-engineering 250, **253**, 257
 - cut slopes 150
 - debris flows 41
 - groundwater 33, 65, 136, 167
 - slope management 269, 272, 273, 274, 275
 - widening 40, 64, 70, 114, 115, 139, 145, 156
 - wire bolsters **253**, 254

