

Index

Page numbers in *italic* denote figures. Page numbers in **bold** denote tables.

- accessibility 14
- adobe 2, 91
 - construction process 92
 - low energy requirement 8–9, 91
 - Pays rémois* 120, 121, 122, 127
 - Portugal 92, 93, 94–99, 94
 - chemistry 95, 97
 - composition 95, 96–98, 99
 - insoluble residue 95, 97
 - mineralogy 95, 96–97
 - physical/mechanical properties 95–96, 98–99
 - texture 95, 97–98
 - sources and function **4**
 - see also* earth construction
- ‘africano’ 40, 42
- aggregate
 - Austrian Alps 71–77
 - GIS-derived data 71, **74**, 75–76, 77
 - grain size and shape 73, **74**, 75, 76, 77
 - ground truthing 71–77
 - petrographic analysis 73, **74**, 77
 - quality 76–77
 - rock types 73, **74**
 - sample analysis 73, 76
 - XRF analysis 73
 - calcareous, in lime mortar 277, 278
 - depletion 59, 60
 - embodied carbon dioxide 9
 - global demand for 2
 - intrusive rocks 217–226
 - cataclasis 219
 - foliation 219, 220
 - grain size 218–219, 220
 - microcracks 218
 - microstructure 219, **221**
 - mineral composition 218, 220
 - multivariate analysis 220, 221–224
 - partial least squares 220, 221–222, 223, 224
 - principal component analysis 220–221, 222–224
 - resistance 218–219
 - studded tyre test 218, 224, 225
 - technical tests 218, 220, 223
 - production 59–60
 - Best Available Concept 7, 63–69
 - energy use 61
 - Europe 2007–2013 64, **66**
 - inventory and planning 64, **65**
 - land use conflict 60–61
 - mass balance 61
 - pollution and emission 62–63
 - quarrying and production 64, **65**
 - reclamation of mined-out areas 64, **65**
 - sustainability 60, **65**, 66–69
 - transport 62–63
 - use in construction 64, **65**
 - recycling 8, **11**
 - sources and function **4**
 - unit value 3
 - aggregate technology 63–64
 - Agios Theodoros quarry packstone **146**, 147, 148, 159–160
 - mechanical properties 155–156
 - physico-chemical properties 150–151, **152**, 153, 154
 - salt weathering 156, 157
 - air lime *see* quick lime
 - alla prima* (wet on wet) technique 294
 - Allard Pierson Museum, Amsterdam 176, 177
 - alluvial fans, as aggregate, Austrian Alps 71, 73, **74**, 76, 77
 - alluvial valley fill, as aggregate, Austrian Alps 71, 73, **74**, 76
 - Alps, Austria, aggregate 71–77
 - Alveolinidae* 119
 - Am Kathagen quarry, Bentheim Sandstone 166, 167, 169
 - Anogyra quarry packstone **146**, 147, 148, 160
 - mechanical properties 155–156
 - physico-chemical properties 151, **152**, 153
 - salt weathering 156, 157, 158
 - anthroposphere 6, 7
 - Antwerp Town Hall 174
 - Aqueduct of Segovia, stone decay 105, 106
 - Aquileia, *spolia* 27, 29
 - ArcGIS 10 software 72
 - Arch of Constantine 25–26
 - archaeology, construction material technology 12–13
 - architecture
 - influence of geology on heritage 8, 101
 - vernacular 91, 101, 113
 - Argentina Square *see* *Piazza de’ Calcari*
 - asphalt **5**
 - unit value 3
 - Asvestolithos Mitsierou **146**, 155–158
 - ‘Augustus Bath’, Badminton House 31
 - Austrian Alps, aggregate 71–77
 - Austrian Mineral Resources Plan 71
 - Aveiro, adobe 92–99, 94
 - Babakale Yolu Quarry 135, 143
 - tuff 136, 137, 138, 139, 140–143
 - Banc Franc chalk 204, 206
 - Baths of Diocletian, building re-use 24, 25
 - Belgium, Obernkirchen Sandstone 174–175

- Bentheim Sandstone 163
 geology and lithostratigraphy 165, 166, 167
 mineralogy and material properties 167–169, 170, 171
 use in Netherlands
 earliest 171, 172
 later 171, 172, 173
 weathering 178–179
- bentonite, in sludge waterproofing 80, **82**, 84–85, 88
- Best Available Concept, aggregate production 7, 63–69
- ‘bianco e nero antico’ 40, 44
- binders
 air-hardened, source and function 2, **5**
 down-cycling 10, **11**
 hydraulic 2
 energy requirement 9
 source and function **5**
 inorganic, historical use 13
- bioremediation, residual sludge 81
- bitumen
 in asphalt **5**
 unit value 3
- black crust, particulate matter 178, 239–240
- breccia, San Severo marble 39–40
 ‘breccia corallina’ 40, 42
- Bremer Sandstone *see* Obernkirchen Sandstone
- brick clay, unit value 3
- bricks 2
 Cormicy sand grey, *Pays rémois* 120, 121, 122, 127
 down-cycling **11**
 embodied carbon dioxide 9, 10
 fired 2
Pays rémois 120, 121, 127, 128
 sources and function **4–5**
 Vargas Palace 255–256, 260, 261
see also adobe
- Brundtland definition of sustainable development 6
- Budapest, building decay 15–16, 239–250
- burning, quick lime, historical 13
- burrstone, *Pays rémois* 120, 127, 128
- calcarenite
 Cyprus **146**, 147–149
 mechanical properties 155–156
 physico-chemical properties 151, **152**, 153, 154
 salt weathering 156–158
 Puglia 183–198
 composition 187–188, 189–191
 conservation 184–186, 188
 water-repellent treatment 189, 195–198
 durability evaluation 194–195
 geology 186
 physico/mechanical properties 187–189, 191–194
 porosity 188, 189, 191, 192–195
 quarries 184, 185, 186
 salt weathering 185, 189
 sampling 186–187
 weathering 184, 188
 XRD 187, 191
- calcite
 in lime mortar 281
 source and function **5**
- cancelli* 36
- capillarity 229, 231, 236
- capillary zone 229
- carbon dioxide
 aggregate 9, 10, 62–63
 cement clinker production 9, 10
 embodied 8, 9
 stone 9, 10
- carbonate rock
 Austrian Alps aggregate 73, **74**, 75
 Cyprus building stone 145–160
- carbonation degree, lime mortar 263–264, **266**,
 267, 277, **280**, 281
- Castel Sant’Angelo, building re-use 24, 25
- cataclasis, granitic aggregate 219
- cement
 clinker production 2
 carbon dioxide 9, 10
 energy requirement 9
 unit value 3
- cementation, heterogeneous 186
- ceramics
 down-cycling **11**
 sources and function **4–5**
see also Zsolnay ceramics
- Cerithium denticulatum* 119, 120, 121
- Cerithium* limestone, *Pays rémois* 119, 120–121, 120,
 123, 128
- chalk
 Cyprus **146**
 mechanical properties 155–156
 physico-chemical properties 150–154
Pays rémois 115, 118, 120, 122
see also Vernon chalk
- Chapel of Christ of Caloco, granite decay 104, 105
- chert, *Pays rémois* 119, 120, 122
- chloropleth maps, *Pays rémois* 115, 118, 119, 122
- CILECCTA project 67
- ‘cipollino rosso’ 36, 42
- ‘cipollino verde’ 36, 43
- Classe, San Severo complex, marble trade 36, 41
- clay
 brick
 sources and function **4–5**
 unit value 3
 ceramic, unit value 3
- clay bricks
 down-cycling **11**
 embodied carbon dioxide 9, 10
 clinker *see* cement, clinker production
- Collado Hermoso, building stone 107–108, 109
- concrete 2
 embodied carbon dioxide 9, 10
Pays rémois 120, 121, 123
 sludge re-use 80

- conglomerate, Trépaill, *Pays rémois* 118, 120, 122, 127
- conservation
of decayed structures 16
Vargas Palace 253–272
- Pendelikon marbles, nanostructured coatings 293–301
- Puglian calcarenites 184–186, 188
water-repellent treatment 189, 195–198
- spatial analysis 114
- TiO₂-SiO₂-PDMS self-cleaning nanocomposites 285–291
- Constantine, Emperor, building re-use 25–26
- Constantinople
Late Antique marble trade 35
spolia 28–29
- Construction and Demolition management 32
- construction materials
decay and weathering 10, 15–16, 103–104
- diversity 2
- GIS-database, *Pays rémois* 113, 115–129
- historical context 1–2, 12–13
location and transport 12
processing 12–13
unit value 2, 3
see also aggregate; stone
- contact angle measurement 298, 299
- copolymerization, TiO₂-SiO₂-PDMS nanocomposites 288, 291
- Cornicy sand grey bricks 120, 121, 122, 127
- cost analysis 52, 54, 56
- Cost-Effectiveness Analysis
masonry end-of-life phase 47–48, 49, 54
hierarchy of goals 48, 50, 51
- cultural geomorphology, Sierra de Guadarrama 102, 104–109
- cultural heritage
building re-use 23–32
conservation 16
use of GIS 113, 114
Vargas Palace 253–272
- effect of pollution 239
- Cyprus
building and decorative stone 145–160
drilling resistance 150, 155–156, 158
mechanical properties 150, 155–156
permeability 154–155
physico-chemical properties 149–150, 151–155
porosity 149–154
salt weathering 150, 156–158
- debris cones, as aggregate 71, 73, 74, 76, 77
- decay
construction materials 10, 103–104
prevention and mitigation 15–16
Sierra de Guadarrama 104–110
- deformation, intrusive aggregate 219
- Deister Sandstone 177
- diatomite, unit value 3
- digital elevation model 72, 73, 76
- diorite, San Severo complex 40
- Ditrupe* limestone, *Pays rémois* 118–119, 120, 120, 122, 123, 127
- Ditrupe strangulata* 118–119, 120
- dolomite
Cyprus 149
source and function 5
- dolostone
Austrian Alps aggregate 73, 74, 75
Sierra de Guadarrama 103, 107
- down-cycling 10, 11
- durability 15
calcarenites 194–195, 198
map 118, 124, 126, 128
- dust, attic
particulate matter 240–250
composition 246, 247, 248
environmental impact 246
microspectroscopy 240, 243, 244, 245, 246, 249
sulphates 248–249
XRD 240, 243, 244, 249
- earth construction 91–99
global distribution 91, 92
Portugal 92–99
see also adobe; rammed earth; wattle and daub
- Earth systems, and use of natural resources 6, 7
- effectiveness analysis 52, 56
- efficiency *see* resource efficiency
- El Escorial 101, 102
- El Espinar
rock weathering 104
Chapel of Christ of Caloco 104, 105
- end-of-life-phase
masonry 47–57
cost analysis 52, 54
Cost-Effectiveness Analysis 47–48, 49
effectiveness analysis 52
effectiveness-cost ratio and matrix 54, 55, 56
- energy, embodied 9, 10
- energy minerals 1, 2
unit value 2, 3
- energy use, aggregate production 61
- European Commission, *Construction Products Directive* (1989) 60, 66
- Euville limestone, *Pays rémois* 120, 121, 123, 127, 128
- exhaustibility 6
- extraction industries
aggregate production 60–61
environmental protection 13
history 12–13
knowledge and processing 13–14
sustainability 6, 8, 60
- Fatma Gerdan Quarry 135, 143
tuff 136, 137, 138, 139, 140–143
- feldspar, in aggregates 218, 220, 222
- ‘fior di pescio’ 40, 43

- 'flint', *Pays rémois* 119, 120, 122
 fluorosilicon, polymeric matrix 294
 fly-ash particles 178, 240, 249–250
 foliation, intrusive aggregate 219
 fossil fuels 1, 2
 Four Tetrarchs, Sack of Constantinople *spolia* 28–29
 freeze-thaw resistance, nanocomposite coating 299
 Freilichtbühne quarry, Bentheim Sandstone
 166, 169, 170
- gabbroid rock**
 as aggregate 218–226
 microstructure **221**
 mineral composition **222**
 multivariate analysis 222–223
 petrographic features **221, 222, 223–226**
 technical properties 223–226
- Gallipoli Castle Bastion 187
- Geographic Information Systems (GIS)
 building materials
 Pays rémois 113, 115–118, 121–129
 see also Pays rémois, GIS-database
 conservation 114
 evaluation of aggregate quality, Austrian Alps 8, 71,
 73, **74**, 76–77
- Geological and Geophysical Institute, Budapest,
 pollution 240, 241, **242**
- geology, influence on architectural heritage 8, 101
- German Wealden sandstone 163–164, 177–178
- Germany, masonry end-of-life phase 47–57
 Cost-Effectiveness Analysis 47–48, 49
- Gerolakkos quarry limestone **146, 147, 148, 149, 160**
 mechanical properties 155–156
 physico-chemical properties 150–151, **152**,
 153, 154
 salt weathering 156, 157, 158
- 'giallo antico' limestone 38, 44
- Gibellina Nuova, *spolia* 31
- glass, recycling 9–10
- gneiss
 Austrian Alps aggregate 73, **74**, 75, 77
 Sierra de Guadarrama 102, 103, 106, 107, 108
- Göbekli Tepe, dimension stone processing 12–13
- grainstone
 Cyprus **146, 148**
 mechanical properties 155–156
 physico-chemical properties 150–154
 Puglia 189–190
- Grand Tour, *spolia* 31
- granite
 Austrian Alps aggregate 73, **74**, 75, 77
 embodied carbon dioxide 9, 10
 San Severo complex 40, 43
 Sierra de Guadarrama 102, 103
 buildings 104–106
 weathering 104
- 'granito del Foro' 40
 'granito della Colonna' 40
- granitoid rock
 as aggregate 218–226
 microstructure **221**
 mineral composition **222**
 multivariate analysis 222–223
 petrographic features **221, 222, 223–226**
 technical properties 223–226
- gravel
 as aggregate **4, 59**
 Austrian Alps 71–77
- Gravina Calcarenite 184, 186, 187
 composition 190–191, 195
 durability evaluation 194–195
 material properties 191–195
 water-repellent treatment 189, 195–198
 weathering 188
- Gros lien chalk 204, 206
- ground truthing, aggregate quality 71–77
- gypsum
 particulate matter 178, 206, 240, 243–250
 unit value 3
- hardening, quick lime 275–282
 history 13
- Hauptsandsteinbank, Obernkirchen Sandstone 164, 166
- Herengracht, Amsterdam 177
- hierarchy of goals, CEA, masonry 48, 50, **51**
- hornblende, in aggregates 218, 220
- hydrocarbons, contamination 79, 81, 89
- Île-de-France cuesta 115, 116
- industry minerals 1, 2
 unit value 2, 3
- intrusive rock, as aggregate 217–226
- Italy, calcarenite 183–198
- Karpasia quarry limestone **146, 147, 148, 149, 160**
 mechanical properties 155–156
 physico-chemical properties 151, **152, 153, 154**
 salt weathering 156, 157
- Kivides quarry packstone **146, 147, 148, 160**
 mechanical properties 155–156
 physico-chemical properties 150–151, **152, 153**
 salt weathering 156, 157, 158
- Kızılkeçili Quarry 135, 143
 tuff 136, 137, 138, 139, 140–143
- La Granja Palace 101
- land rehabilitation, residual sludge 81
- land use, aggregate production 60–61
- landfill, sludge disposal 12, 79, 80, 81, **82, 84–85**
lapis Atracius see 'verde antico'
lapis Lacedaemonius see 'porfido verde antico'
lapis Porphyrites see 'porfido rosso antico'
- Late Antiquity, Ravenna marble trade 35, 36, 41–44
- Lateran Basilica, building re-use 26
- Life Cycle Assessment 32, 48, 54, 60, 67, 68, 69
- Life Cycle Cost 60, 67, 68, 69

- Life Cycle Working Environment 48, 54
- lime
 calcitic, in lime mortar 277, 278
 production, Middle Ages 27
 source and function **5**
 unit value 3
see also quick lime
- limestone
 Austrian Alps aggregate 72, 73, **74**, 75, 77
 bioclastic
 Cyprus **146**, 149
 mechanical properties 155–156
 physico-chemical properties 151, **152**, 153, 154
 salt weathering 156, 157, 158
Cerithium, *Pays rémois* 119, 120, 123, 128
Ditrupe, *Pays rémois* 118–119, 120, 120, 122, 123, 127
 Euville, *Pays rémois* 120, 121, 123, 127, 128
 Göbekli Tepe 12–13
 lacustral *Limnaea*, *Pays rémois* 119, 120, 120
 Lutetian 203–215, 204
 durability evaluation 206–208, 210–214
 atmospheric pollution 206–207, 214
 salt weathering 206, 211–214
 lithostratigraphy 205
 petrography 208–209
 physical properties 204, 206, 209–210
 porosity 206, 208–210
 roughness 207, 213–214
 types 204, 205, 206
 miliolid, *Pays rémois* 119, 120, 123, 127, 128
 Mokattam, salt weathering simulation 231, 232, 233–236
 nummulitic, *Pays rémois* 120, 122
 orange granular *Cerithium*, *Pays rémois* 120–121
 potamide, *Pays rémois* 119, 120, 128
 reef
 Cyprus **146**, 149
 mechanical properties 155–156
 physico-chemical properties 151, **152**, 153, 154
 salt weathering 156, 157, 158
 Saint-Maximin, *Pays rémois* 120, 128
 Saint-Pierre-Aigle, *Pays rémois* 120, 128
 San Severo marble 37–38, 44
 Savonnières, *Pays rémois* 120, 121, 123, 128
 Sierra de Guadarrama 102, 103, 107–109
 siliceous, *Pays rémois* 120
 silicified, *Pays rémois* 119, 120, 122
 source and function **5**
 sublithographical, *Pays rémois* 119, 120, 122, 128
Limnaea limestone, *Pays rémois* 119, 120, 120
 Lower Saxony Basin, Lower Cretaceous sandstone 163–165
 Luserna stone quarry basin 80, 88
 Lympia quarry packstone **146**, 147, 148, 159
 mechanical properties 155–156
 physico-chemical properties 150–151, **152**, 153, 154
 salt weathering 156, 157
 Manzanares Castle 101
 marble
 embodied carbon dioxide 9, 10
 Late Antique San Severo complex 35–44
 polychrome 36
 white-grey 36, 40–41
 Pendelikon 293–301
 marl, Austrian Alps aggregate **74**, 75, 76, 77
marmor Carystium *see* ‘cipollino verde’
marmor Celticum *see* ‘bianco e nero antico’
marmor Claudianum *see* ‘granito del Foro’
marmor Iassense *see* ‘cipollino rosso’
marmor Luculeum *see* ‘africano’
marmor Numidicum *see* ‘giallo antico’
marmor Phrygium *see* ‘pavonazetto’
marmor Sagarium *see* ‘breccia corallina’
marmor Synnadicum *see* ‘pavonazetto’
 masonry
 end-of-life phase 47–57
 Cost-Effectiveness Analysis 47–48, 49
 hierarchy of goals 48, **50**, **51**
 mass balance, aggregate production 61
 material efficiency 7
 Material Flow Analysis 48, 50–52, **53**, 54
 Mausoleum of Hadrian, building re-use 24, 25
 Mausoleum of Santa Constanza, building re-use 26
 metal materials, *Pays rémois* 120, 121, 123
 metal ores 1, 2
 unit value 2, 3
 mica
 in aggregates 218, 220, **222**
 unit value 3
Microdium calcareous sandstone, *Pays rémois* 118–119, 120, 122, 127
 Middle Ages, building re-use 27–29
 miliolid limestone 119, 120, 123, 127, 128
 minerals, annual total amount extracted 1, 2
 Mitsero quarry limestone **146**, 147, 148, 149, 160
 mechanical properties 155–156
 physico-chemical properties 150–151, **152**, 153, 154
 salt weathering 156, 157
 Mokattam limestone, salt weathering simulation 231, 232, 233–236
 monadnocks, Île de France 115, 116
 mortars
 2
 lime, air-hardening 275–282
 binder-to-aggregate ratio 275, 276, 277, 280, 281
 carbonation degree index 277, **280**, 281
 packing density 275–276, 277–280, 281–282
 physical-mechanical properties 280–281
 pore size distribution 280, 281
 porosity 276, 277, **278**, **280**, 281
 standards 275, 281, 282
 strength **280**, 281
 voids ratio 276–277, 278
 water-to-binder ratio 276–277, 278, 279, 281
 repair rendering 16, 254–272
 source and function **5**

- mortar (*Continued*)
 standards 275, 281, 282
 Vargas Palace
 original 255–256
 characterization 259–261
 repair rendering 254–255
 adhesion 257, 263, 264, 271
 characterization 257, 259
 chromatic differences 270–271
 mineralogy differences 263–264, 266, 267
 preparation 256–257, 258
 shrinkage 257, 261, 262, 263, 271
 textural differences 267–270
 workability 257, 261, 271
- morVar 255, 260, 261
- mosaic floors, re-use of Roman stone 27, 28
- mud, as binder 5
- Museum of Applied Arts, Budapest, pollution
 240, 241, **242**
- nanocomposites
 Pendelikon marble 293–301
 TiO₂-SiO₂-PDMS 285–291
- nanosilica coating 294
- neoclassicism, *spolia* 30–31
- Nesselberg Sandstone 177–178
- Netherlands
 imported building stone 163–179
 imported German stone, earliest use 171, 172
- Neues Museum, Berlin, *spolia* 31–32
- Ningbo Museum, China, material re-use 32
- Norway, aggregate depletion 59, 60, 62, 63, 64
- Notre Dame de Vetheuil 204
- Nummulites laevigatus* limestone, *Pays rémois*
 120, 122
- Obernkirchen Sandstone 163
 geology and lithostratigraphy 163–165
 Hauptsandsteinbank 164, 166
 mineralogy and material properties 167, 168,
 169, **171**
 use in Netherlands 173–177
 weathering 178–179
- Octaviae Porticus*, building re-use 25
- Old St Peter's, Rome, building re-use 26
- opus sectile* 36, 38, 44
- Orbitolites complanatus* 119
- Pachna quarry grainstone **146**, 147, 148, 160
 mechanical properties 155–156
 physico-chemical properties 150–151,
152, 153
 salt weathering 156, 157
- packing density, lime mortar 275–276, 278–280, 281
- packstone
 Cyprus **146**, 147–149
 mechanical properties 155–156
 physico-chemical properties 150–154
- Palazzo Cancellaria, Rome, *spolia* 29, 30
- Palazzo Crescenzi, Rome, building re-use 27
- Palazzo de Lorenzo, Sicily, *spolia* 31
- Palazzo della Torre, Udine, *spolia* 31
- Palazzo Personé, Lecce 187
- Palazzo Savelli, building re-use 29
- PANTURA project 67
- Paris, Lutetian limestone 203–215
 partial effectiveness value 52, 55
 particulate matter 178
 and degradation of architectural ceramics
 239–250
- 'pavonazzetto' 39–40, 43
- Pays rémois*
 chloropleth maps 115, 118, 119, 122
 durability map 118, 124, 126, 128
 geography and geology 115, 116, 117
 GIS-database 113, 115–118, 121–129
 building materials 121–129
 SDE 118, 122–124, 127, 128–129
 history 114
 local stone 118–120, 123, 124
 non-stone materials 121
 regional or extraregional stone 120–121,
 123, 124
- PDMS (polydimethylsiloxane) *see* TiO₂-SiO₂-PDMS
 nanocomposites
- Pendelikon marble
 nanocomposite coating 293–301
 contact angle 298, **299**
 effectiveness of treatment 294–298, 301
 freeze-thaw resistance 299
 lamination technique 294, 295
 porosity and absorption 297, 298, **299**
 reversibility 299–300
 SEM/EDX data 294, 295, 296, 297, 299, 300
 surface roughness 297, 298, 301
- perlite, unit value 3
- Petra Gerolakkou **146**, 155–158
- Petra Karpasias **146**, 155–158
- Petra Lympion **146**, 147, 155–158
- Petra Pachnas **146**, 147–149, 155–158
- Philadelphion of Constantinople, Four Tetrarchs
spolia 29
- photocatalytic oxidation reaction 16, 285, 290, 291
- phyllite, Austrian Alps aggregate 73, **74**, 77
- Piazza de' Calcari*, lime production 27, 28
- Piedmont, residual sludge 80–89
- Pierre de Paris *see* limestone, Lutetian
- Pierre de Vernon 203
- Pietra Leccese Calcarenite 184
- Pieve Vergonte *see* sludge, dimension stone processing,
 pilot site testing
- Pisa Cathedral, St Ranieri portal *spolia* 28
- pollution
 aggregate production 62–63
 atmospheric, Lutetian limestone 206–207
 building decay 15–16

- effect on Zsolnay ceramics 239, 240
- residual sludge 79, 81, 89
- 'porfido rosso antico' 38–39, 43
- 'porfido verde antico' 38, 43
- porosity
 - building and decorative stone, Cyprus 149–154
 - calcarenite 188, 189, 191, 192–195
 - lime mortar 276, 277, **278**, **280**, 281
 - Lutetian limestone 206, 208–210
 - Pendelikon marble 297, 298, **299**
- porphyry, San Severo marble 38–39
 - see also* 'porfido rosso antico'; 'porfido verde antico'
- Portland cement 2
 - energy requirement 9
 - source and function **5**
- portlandite, lime mortar 277, 278
- Portugal, earth construction 92–99
- Potamides* limestone 119, 120, 128
- Prastio quarry packstone **146**, 147–148, 160
 - mechanical properties 155–156
 - physico-chemical properties 151, **152**, 153, 154
 - salt weathering 156, 157, 158
- preservation, heritage structures 3
- preservation orders 29–30
- Proconnesos marble 35, 41–42
- Puglia, calcarenite 183–198
 - geology 186
- pumice, unit value 3
- quarries
 - rehabilitation 12, 81, 85, 88
 - use of sludge 80
- quarrying *see* extraction industries
- quartz, in aggregates 218, **222**
- quartzite, Austrian Alps aggregate 73, **74**, 75
- quick lime 2
 - historical production 13
 - source and function **5**
- rammed earth 2, 91–99
 - low energy requirement 8–9
 - Portugal 92, 93
 - sources and function **4**
 - see also* earth construction
- Ravenna, Late Antique marble trade 35, 36, 41–44
- raw materials
 - annual total amount extracted 1, 2
 - and unit value 3
 - energy issues 8–9
 - historical context 12–13
 - location and transport 12
 - processing 12–13
 - resource management and efficiency 7–8
 - secondary use 9–12, 23–32, 79
 - see also* down-cycling; re-use; recycling
 - sources and functions **4–5**
 - sustainability 6, 7
 - re-use 10, **11**
 - sustainability 32
 - traditional materials in built heritage 23–32
 - Syracuse Cathedral 24
 - see also* preservation orders; recycling
 - recycling
 - of resources 6, 7, 9–12, **11**
 - adobe 91
 - unburnt soil 9
 - see also* down-cycling; raw materials, secondary use; re-use
- Reims 114, 116, 117
 - geomaterials 125, 126
 - see also Pays rémois*
- Renaissance, *spolia* 29–30
- Requijada, Virgen de la Vega chapel, limestone decay 108–109, 110
- resource efficiency 7–8
- resource management 6–7
- resource productivity 7
- Reubens' House, Antwerp 175
- Roman world, ancient building re-use 24–27
- Romberg quarry, Bentheim Sandstone 165, 166, 167, 168, 169
- 'rosso de Verona' limestone 37, 44
- roughness, limestone 207, 213–214
- Royal Palace, Amsterdam 172, 173, 175
- Sack of Constantinople, Portrait of the Four Tetrarchs *spolia* 28–29
- St Mark's Basilica, Venice, *spolia* 28–29
- St Martin's Tower, Groningen 173, 174
- St Peter's Basilica, Rome, building re-use 26
- St Plechelmus' Basilica, Oldenzaal 171, 172
- St Rombout's Cathedral, Mechelen 173
- Saint-Maximin limestone
 - Lutetian limestone 204
 - Pays rémois* 120, 128
- Saint-Pierre-Aigle limestone, *Pays rémois* 120, 128
- salt weathering 229–236
 - construction materials 10, 15, 101, 103–104
 - Cyprus building stone 150, 156–158
 - experimental simulation 229–231
 - Mokattan limestone 231, 232
 - samples 230–231, 235–236
 - temperature/humidity 230–231, 233, 234
 - weight change 234–235
 - weight recording 230, 233–234
 - Lutetian limestone 206
 - Puglian calcarenite 185, 189
 - Vernon chalk 206
- San Lorenzo, Genoa, building re-use 27
- San Salvatore, Spoleto, building re-use 27
- San Severo in Classe complex, Ravenna 36, 37, 38, 39
 - Late Antique marble 35, 36, 40–44
- sand
 - as aggregate **4**, 59
 - in mortar 2

- sandstone
 Austrian Alps aggregate **74**, **75**, **76**, **77**
 calcareous *Microdium*, *Pays rémois* 118, **120**, **122**, **127**
 embodied carbon dioxide **9**, **10**
Pays rémois 118, **120**, **122**, **127**
 Sierra de Guadarrama **102**, **103**
see also Bentheim Sandstone; Obernkirchen Sandstone
- Santa Maria, Cosmedin, mosaic floor **27**, **28**
- Santa María de la Sierra, building stone **109**, **110–118**
- Santa Maria degli Angeli **24**, **25**
- Sant'Eufemia, Grado, building re-use **27**
- Savonnières limestone, *Pays rémois* **120**, **121**, **123**, **128**
- schist, Austrian Alps aggregate **72**, **73**, **74**, **75**, **76**, **77**
- secondary raw materials, sludge **79**
- secondary use **9–12**, **23–32**, **79**
see also down-cycling; re-use; recycling
- Segovia **101**, **102**
 Aqueduct, stone decay **105**, **106**
- 'serpentino' **38**
- serviceability **14**
- Settis, Salvatore, *Memoria dell'antico nell'arte italiana* (1986) **23**
- Sierra de Guadarrama **101–110**
 carbonate buildings **107–109**
 'cultural geomorphology' itinerary **104–109**
 geology **102–103**
 granitoid buildings **104–106**
 metamorphic rock buildings **106–107**
 weathering and stone decay **103–110**
- silica, nanocomposite coating **294**
- SiO₂ *see* TiO₂-SiO₂-PDMS nanocomposites
- slate, embodied carbon dioxide **9**
- sludge, dimension stone processing **12**, **79–89**
 bioremediation **81**
 contamination **79**, **81**, **89**
 grain size **79**, **82**, **83**, **84**, **85**, **86**, **87**
 hydraulic conductivity **82**, **83**, **84**, **86**, **88**
 laboratory testing **81–82**, **83–85**, **86**, **87**
 land rehabilitation **81**, **82**, **85**, **88–89**
 pilot site testing **82–83**, **84**, **85**, **86**, **87**, **88**
 re-use as artificial soil **81**, **82–83**, **85**, **88–89**
 re-use in construction industry **12**, **80–81**
 re-use as filler **80–81**, **82**, **85**, **88**
 re-use as waterproofing **80**, **81**, **82**, **84–85**, **88**
 secondary raw materials **79**
 shear strength/stability **82**, **83–85**, **86**, **87**, **88**
- society, material requirements of **6**, **7**
- soil
 brick production **2**
 unit value **3**
 as construction material **2**
 sources and function **4**
- residual sludge re-use **81**, **82–83**, **85**, **88–89**
- unburnt
 low energy requirement **8–9**
 re-use **11**
 recycling **9**
- soot particles **240**, **249–250**
- Sotosalbos Church of San Miguel Archangel, building stones **107**, **108**, **109**
- Spain
 geology and architecture **101**
 Vargas Palace **253–272**
- spatial analysis, building conservation **114**
- spherules, in dust samples **243–250**
- spolia* **23–24**, **26**, **27**, **28–30**
- Standard Deviation Ellipse, *Pays rémois* building materials **118**, **122–124**, **127**, **128–129**
- standards, mortar **275**, **281**, **282**
- stone
 crushed
 recycling **11**
 sources and function **4**
see also aggregate
 dimension **2**
 Cyprus **145–160**
 German sandstone **163–178**
 history of processing **12–13**
Pays rémois **118–121**
 processing waste **12**, **79–89**
 Puglia **183–198**
 recycling **11**
 sludge **79–89**
 sources and function **4**
 unit value **3**
 embodied carbon dioxide **9**, **10**
- studded tyre test, intrusive aggregate **218**
- sulphates, attic dust **248–249**
- sulphation **248–250**
- sulphur gas **239**
- sustainability **6–12**
 aggregate production **60**
 embodied energy **9**
 energy use and emissions **8–9**
 extraction industries **6**, **8**
 re-use and recycling **32**
 resource management and efficiency **6–8**
- Syracuse Cathedral, building re-use **24**
- tabique* (wattle and daub), Portugal **92**
- taipa* (rammed earth), Portugal **92**, **93**
- technology, archaeological **12–13**
- technosphere **7**
- Temple of Apollon Smintheus
 geology **135**
 tuff **133–143**, **134**
 chemistry, petrology, mineralogy **139**, **141–143**
 physical properties **135–138**, **139–141**
 provenance **143**

- TEOS (tetraethoxysilane) 285, 286
 hydrolysis 287–288, 291
- Terraced Marine Deposits 184, 186, 187
 calcarenite weathering 188
 composition 189–191
 durability evaluation 194–195
 material properties 191–195
 water-repellent treatment 189, 195–198
- tesserae* 36
- Theatre of Marcellus, Rome, *spolia* 29, 30
- Theatre of Pompey, Rome, *spolia* 29
- tiles, sources and function 4
- TiO₂-SiO₂-PDMS nanocomposites 16, 285–291
 copolymerization 288, 291
 differential thermal analysis 286, 288, 291
 DRMS 289, 290, 291
 FTIR spectroscopy 286, 287, 288, 289, 290, 291
 photocatalytic oxidation 16, 285, 290, 291
 product assessment 286, 287
 SEM 286, 288, 289, 291
 thermogravimetric analysis 286, 288, 291
 treatment assessment 289–291
 X-ray diffraction 286, 287, 288, 291
- transgression, Puglia calcarenous platform 186
- transport, aggregate production 62–63
- Troodos Ophiolite Complex 147, 148
- TTIP (titanium tetraisopropoxide) 285, 286, 291
- tuff
 calcareous *see* calcarenite
 Temple of Apollon Smintheus 133–143
 chemistry, petrology, mineralogy 139, 141–143
 physical properties 135–138, 139–141
 provenance 143
- Turkey, tuff, Temple of Apollon Smintheus 133–143
- uranium 1, 2
- valley fill, as aggregate, Austrian Alps 71, 73,
 74, 76
- Vargas Palace, Granada 254, 255
 repair rendering mortar 254–255
 restoration 253–272
- Venetian Republic, *spolia* 31
- Verbano Cusio Ossola quarry basin
 residual sludge 80–89
 pilot site testing 82–83, 84, 85, **86**, **87**, 88
 verde antico 40, 43
 vermiculite, unit value 3
- Vernon chalk 203–215, 204, 206
 durability evaluation 206–208, 210–214
 atmospheric pollution 206–207, 214
 salt weathering 206, 211–214
 petrography 208–209
 physical properties 206, 209–210
 porosity 206, 208–210
 quarries 204
 roughness 207, 213–214
- Villacastín Church, granite decay 105–106
- Virgen de la Vega chapel, limestone decay 108–109, 110
- Vitruvius, Marcus (c.80BC–c.15BC), *De Architectura libri decem* 275
- wackestone
 Cyprus **146**, 149
 mechanical properties 155–156
 physico-chemical properties 150–154
- waste
 dimension stone processing 12, 79–89
 end-of-life phase masonry, Germany 47–57
see also sludge
- waterproofing, sludge re-use 80, 81, **82**, 84–85, 88
- wattle and daub, Portugal 92
- weathering
 Bentheim and Obernkirchen sandstones 178–179
 Pendelikon marble 293
 Puglian calcarenite 184, 188
 salt *see* salt weathering
- wet-on-wet lamination
see alla prima (wet on wet) technique
- wick effect
see capillarity
- wood materials, *Pays rémois* 120, 121, 123
- Wood quarry, Bentheim Sandstone 166, 170
- workability 14
- Zsolnay ceramics, effects of pollution 239, 240