

- AAFA, *see* fly ash geopolymers
- abiotic resource depletion potential, 198
- ACS-ISO, 346
- activating solutions
- geopolymers, 50–66
 - alkali hydroxide solutions, 51–6
 - alkali silicate solutions, 56–62, 64
 - other activators, 64–6
- AfT-phase, 171
- ageing, accelerated, of geopolymers, 139–64
- crystallisation during ageing of gels, 141–2
 - crystallisation during synthesis of gels, 140–1
 - fly ash geopolymers, 153–63
 - crystallisation of zeolites faujasite and sodium P1, 156
 - effect of ageing on strength, 153–4, 156
 - effect of zeolite crystallisation on strength, 158–63
 - elemental composition of fly ashes and GGBS, 154
 - geopolymer synthesized from FA3 and GGBS, 158
 - phase changes, 156–7
 - polished section of geopolymer synthesized from FA1, 159
 - SEM examination, 157–8
 - metakaolin geopolymers, 145–53
 - accelerated ageing at 95°C, 146–7
 - ageing at ambient temperature, 145–6
 - effect of alkali type, 153
 - effect of temperature, 151–2
 - mechanism of strength loss during ageing, 150–1
 - phase changes, 147–8
 - SEM examination, 149–50
 - test procedure, 144
 - tests, 142–4
 - considerations, 143–4
 - need for accelerated ageing tests, 142–3
- Al MAS NMR, 129
- albite, 186, 231
- Al:Ca ratio, 364
- alkali activated materials, 379
- see also* geopolymers
 - alkali aluminosilicate, 2
 - alkali hydroxide solutions, 51–6
 - caesium hydroxide, 55–6
 - lithium hydroxide, 53
 - potassium hydroxide, 55
 - rubidium hydroxide, 55
 - sodium hydroxide, 53–5
 - standard enthalpies of dissolution, 52
 - viscosities as a function of molality, 51
 - alkali silicate solutions, 56–62, 64
 - engineering properties, 62, 64
 - density of sodium silicate solutions, 65
 - potassium silicate viscosities, 63
 - sodium silicate viscosities, 63
 - solubility and phase equilibria, 56–8
 - compositional regions, 57
 - crystallisation isotherms, 56
 - speciation, 58–62
 - ²⁹Si NMR for species identification, 59
 - silicate monomer and dimer equilibrium constants, 62
- alkali-activated cement, 414
- alkali-aggregate reaction, 384
- alkaline aluminosilicate cements
- experience of application, 257–61
 - fireproof doors for elevators, 262

- glassware furnace lining fragments, 260
- heat-resistant aerated concrete
 - structure, 260
 - testing of heat-resistant adhesive, 260
- geocement composition and pre-curing conditions
 - compressive strength, 254
 - residual strength after firing at 800°C, 254
 - shrinkage after firing at 800°C, 254
- mineral transformation depending on cation type, 230
- mix proportion, phase composition and properties, 250–7
 - compressive strength and thermal shrinkage, 252
 - isoparametric diagrams of thermal shrinkage, 259
 - optimal mixes of heat resistant Na-based geocement-based composites, 257
 - solutions for shrinkage control, 253
 - thermal shrinkage vs heating temperature, 258
- Na-K geocement – OPC clinker after firing
 - temperature of crystallisation measured by DTA, 251
 - XRD patterns after firing at 800°C, 1000°C, 1300°C, 250
- phase composition after curing, 229–50
 - alkali activated cements after firing vs cation type, 249
 - chemical composition of raw materials, 233
 - fly ash-based geocements DTA patterns, 237
 - geocements with $\text{SiO}_2/\text{Al}_2\text{O}_3$ after firing at 800°C, 236
 - hydration products composition vs geocement compositions, 234
 - phase transformation at low temperatures, 231–2
 - transformation in geological process, 229–1
- phase transformation during heating, 235–50
 - alkali activated metakaolin and fly ashes after steam curing, 244
 - aluminosilicate component type and $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio, 238, 241–3
 - cation type and direction of phase transformation, 248–50
 - effect of clay mineral and type of activator, 239–40
 - geocements after firing at 800°C, 242
 - initial alkalinity ($\text{Na}_2\text{O}/\text{Al}_2\text{O}_3$ ratio), 243, 245, 248
 - pre-curing mode, 235–6, 238
 - $\text{SiO}_2/\text{Al}_2\text{O}_3$ molar ratio and initial geocements dehydration products, 241
 - phases formed in alkali activated fly ash cements
 - $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 3.6\text{SiO}_2 \cdot x \text{H}_2\text{O}$, 247
 - $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 4.0\text{SiO}_2 \cdot x \text{H}_2\text{O}$, 247
 - $0.5\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 4.0\text{SiO}_2 \cdot x \text{H}_2\text{O}$, 247
 - relative intensity of crystallisation
 - compressive strength of ‘geocement-chamotte’ composition, 256
 - density of ‘geocement-chamotte’ composition, 256
 - residual strength of ‘geocement-chamotte’ composition, 256
 - thermal shrinkage of ‘geocement-chamotte’ composition, 256
 - transformation in geological process, 230
 - XRD patterns of compositions
 - $0.5\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 4.0\text{SiO}_2 \cdot x \text{H}_2\text{O}$, 246
 - $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 3.6\text{SiO}_2 \cdot x \text{H}_2\text{O}$, 245
 - $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 4.0\text{SiO}_2 \cdot x \text{H}_2\text{O}$, 246
- alkali-silica reaction, 384
- Al–O bonds, 371
- alumina, 412
- aluminium, 42–3, 101–7
 - ‘Aluminium of Greece,’ 346
- aluminium oxide, 213
- aluminosilicate, 2, 81, 122
 - dehydroxylation of 1:1 layer-lattice
 - halloysite dehydroxylation, 298
 - kaolinite dehydroxylation, 296
 - dehydroxylation of 2:1 layer-lattice
 - pyrophyllite dehydroxylation, 299
 - geopolymers, other formation methods, 308–11
 - soft chemical synthesis, 310–11
 - solid-state synthesis, 309
 - octahedral Al–O and tetrahedral Si–O sheets

- 1:1 layer lattice, 297
- 2:1 layer lattice, 297
- powder pattern of dehydroxylated halloysite, 298
- aluminosilicate calcium hydrates, 380
- aluminosilicate glass, 22
 - major oxide composition, 25
 - phase diagram, 23
 - XRD patterns before and after thermal treatment, 27
 - XRD patterns of Australian coal fly ashes, 28
- American Concrete Institute Committee 217, 225, 363
- analcime, 96, 142, 186, 231, 232, 252
- anorthite, 345
- anorthoclase, 231
- ANS 16.1 test, 410, 412–13
- antimony, 429
- argon, 324
- Argonne National Laboratory, 414
- arsenic, 426–7
- arsenious acid, 427
- AS1530 4, 328
- ASTM C150, 385
- ASTM C595, 385
- ASTM C684, 143
- ASTM C1157, 385
- ASTM C1260-94, 180, 181
- ASTM E119, 328
- Attenuated Total Reflectance-Fourier Transform Infrared Spectroscopy, 120
- Australian Standard AS3600, 217, 219, 222
- Australian Standard AS3972, 387–9
- Aznalcollar mine, 267
- back-reaction, 408
- barium, 429
- barium hydroxide, 412
- bentonite, 429
- Bingham visco-plastic fluid model, 127
- bitumen, 414
- bitumenisation, 405
- black coal fly ash, 426
- blast furnace slag, *see* ground granulated blast furnace slag
- boron, 427–8
- borosilicate glass, 409, 411
- Bragg diffraction condition, 334
- brown coal fly ash, 426
- Brunauer-Emmett Teller, 404
- BS 1881, 143
- cadmium, 434
- caesium, 428–9
- caesium aluminosilicate, 78–9, 428
- caesium hydroxide, 55–6
- calcined kaolinite clay, *see* metakaolin
- calcium, 84, 125
- calcium aluminate cement, 139, 144, 333
- calcium (alumino) silicate hydrate, 431
- calcium ferronickel slags, 369, 371
- calcium fluoride, 412
- calcium hydroxide, 333, 338
- calcium oxide, 212, 345
- calcium silicate hydrates, 143, 335, 338, 361, 364, 370, 413, 428
 - gel, 167, 352
- calcium silicates, 81, 228
 - hydrated, 90
- calcium zincate, 432
- calorimetry, 125–6
- capillary water absorption coefficients, 280
- carbon cap-and-trade system, 394
- cementation, 405
- cementitious gels, 89–92
 - C-S-H gel structural model, 90
 - proposed structural model for N-A-S-H gel, 91
- cenospheres, 20
- Certified Emission Reductions, 397
- chabazite, 142, 231, 232, 309
- chabazite-Na, 96, 109
- chamotte, 186, 261
- chemical durability, of geopolymers, 167–90
 - acid attack, 172–6
 - changes in mineralogy of mortars, 176
 - compressive strength of Portland cement and alkali activated fly ash, 173
 - mechanical strength of AAFA and OPC mortars, 175
 - mechanism of corrosion, 172
 - alkali silica reaction, 180–1, 183
 - formation of expansive products by ASR, 181
 - zeolite transformation, 181
 - frost attack, 189–90
 - general aspects, 167–8
 - high temperature and fire resistance, 183–9

- resistance to corrosion of steel
 - reinforcement, 176–9, 180
 - sulphate attack and sea water attack
 - resistance, 168–71
 - chert, 384
 - chromite, 345
 - chromium, 431–2
 - class C ash, 40–1
 - class F ash, 18, 39–40
 - clays
 - calcined, 429
 - conventional and alternative methods of pre-treatment, 294–312
 - reproduction of thermal dehydroxylation effects
 - chemical pre-treatment, 306–8
 - mechanochemical processing, 304–6
 - planetary ball mill and vibratory mill, 304
 - reproduction of thermal dehydroxylation effects, 302, 304–6
 - Clean Development Mechanism project, 395, 397
 - Climate Change Levy, 395
 - clinoptilolite, 142
 - CML method, 198
 - coal, 16
 - coal fly ash
 - chemistry, and inorganic polymer cements, 15–33
 - aluminosilicate glass chemistry, 22
 - glass behaviour in IPC formation, 29–32
 - glass chemistry, 24–6
 - major minerals in Australian bituminous coals, 19
 - origin and history, 16–19
 - particle morphology, 19–22
 - coal fly ash glass
 - chemistry, 24–6
 - ASG oxide composition, 25
 - XRD patterns of ASG before and after thermal treatment, 27
 - XRD patterns of Australian coal fly ashes, 28
 - in IPC formation, 29–32
 - two dimensional structure of crystalline and vitreous silica, 30
 - coalification, 16
 - cobalt, 435
 - coefficient of variation, 285
 - computed tomography, 336
 - congruent dissolution, 407
 - construction industry
 - addressing standards and regulations framework, 385–90
 - drivers for standards development, 386–7
 - insurance and risk assessment, 389–90
 - long-term global standards
 - development, 388
 - material flow for cement, 386
 - prescription vs performance standards, 387–8
 - short-term regulatory barriers, 388–9
 - cement market analysis, 390–1
 - cement production in 2005, 391
 - direct CO₂ emissions from cement production, 392
 - drivers for cement demand, 390–1
 - global cement demand by region and country, 392
 - size of cement market, 390
 - total estimated CO₂ emission of geopolymer binder, 394
 - commercialisation of geopolymers, 379–400
 - effect of climate change and carbon trading on opportunities, 393–8
 - carbon trading market, 397–8
 - different emission reduction instruments, 394–6
 - life cycle analysis, 393–4
 - tax, trade and permit allocation, 396–7
 - opportunities for AAM, 398–9
 - carbon trading opportunities, 399
 - focus on climate change, 398
 - 'green' as competitive advantage in market, 398
 - overcoming regulatory obstacles, 399
 - reasons for not commercialising AAM technology, 381–3
 - barriers overcome, 384
 - brief history of R&D and commercial efforts, 381–3
 - remaining barriers, 384–5
- copper, 430
- corundum, 261, 334
- creep coefficient, 222
- cristobalite, 26, 241, 242, 335, 345
- crystallisation, 24, 140

- C-S-H gel, *see* calcium silicate
cumulative energy demand, 198
- Davidovits geopolymer synthesis, 308
dealumination, 174, 175
deconvolution, 77–8
dehydroxylation, 318
devitrification, 24
differential scanning calorimetry, 324
 quasi-isothermal modulated, 125
differential temperature analysis, 324
Diffrac_{plus} Software, 347
diffraction techniques, 127–9
dilatometry, 316, 324
DIN 38414 – S4, 289
DIN EN 206-1//DIN 1045-2, 204, 205, 206
diopside, 361, 370
dissolution-precipitation phenomenon, 168
dolomite, 412
dry-curing, 216
DTA, *see* differential temperature analysis
dyes, 436
- Ecoinvent database, 197
E-Crete, 388
EDXRD, *see* energy dispersive X-ray
 diffractometry
efflorescence, 55
electric arc slag, 345
energy dispersive X-ray diffractometry, 128,
 129, 132
Engelhardt equation, 99
Environmental scanning electron microscopy,
 130
ettringite, 171, 223, 431
Eurobitum, 414
Eurocode (EN1991-1-2:2002), 328
Eurocode (EN1991-1-2 [40]), 329, 330
European Union Emission Trading Scheme,
 395, 397
europium, 435
EXAFS, 426
- faujasites, 141, 148, 156, 157, 168, 231
fayalite, 345, 360, 361, 362
Fe:Cr ratio, 364
feldspars, 141, 183, 230
feldspathoids, 185, 230
ferrihydrite, 325, 335
fly ash, 2, 4–5, 39–42, 345, 352
 class C ash, 40–1
 class F ash, 39–40
 pseudo-ternary composition, 40
 and glass chemistry, 41–2
 geopolymerisation, 41
 nanostructure/microstructure, 89–114
 cementitious gels, 89–92
 geopolymer microstructure, 111–14
 N-A-S-H gel, 96–9, 101–11
 polymerisation, 92–6
fly ash geopolymers
 alkali activated, mechanical strength, 175
 alkali-silica reaction-induced expansion,
 181
 changes in mineralogy of mortars, 176
 compressive strength evolution
 activated with NaOH and with sodium
 silicate solution, 169
 alkali activated, exposed to acid
 solutions, 173
 mortars activated with a sodium
 silicate solution, 170
 mortars activated with an 8M NaOH
 solution, 170
 diffractograms of samples tested at
 ambient and at high temperatures,
 186
 effect of accelerated ageing
 high calcium, 155
 low calcium, 155
 effect of changes in activator composition
 on ageing, 160
FA3 paste
 activated with varying alkali content,
 161
 zeolite P content, 162
flexural and compressive strengths, 187
fracture surface before and after high
 temperature exposure, 337
leaching of Cd²⁺ from matrices, 435
low-calcium concrete, engineering
 properties, 211–25
mechanical strength evolution, 332
mercury intrusion porosimetry data, 338
microanalysis of solution N-activated
 mortar subjected to accelerated
 test, 182
SEM back-scattered electron image of
 FA1 paste, 162
silicate-activated, extraction of Pb, 425
strength development profiles of
 geopolymer mortars, 154

- TGA/DTA results, 325
- thermal expansion showing regional breakdown, 317
- thermal shrinkage, 322
- variation in i_{corr} vs time, 179
- variation in residual bending and compressive strength in cold samples, 185
- forsterite, 345
- Fourier Transform Infrared spectroscopy, 365–8
- freeze-thaw-resistant concrete, 204, 205
- FRITSCH pulveriser, 345
- FTIR, *see* Fourier Transform Infrared spectroscopy
- FTIR Spectrometer Model 1000, 347
- galliogermanates, 312
- gallium-germanium analogue, 309
- garnets, 228
- gehlenite, 335
- gel nuclei, 124
- general blended cement, 388
- geopolymer concrete, 212
 - compressive strength, 221
 - effect on compressive strength
 - curing time, 215
 - water-to-geopolymer solids ratio, 214
 - engineering properties, 211–25
 - heat-cured
 - acid resistance, 224
 - and ambient-cured, drying shrinkage, 223
 - change in compressive strength, 221
 - total strain and drying shrinkage strain, 222
 - indirect tensile splitting strength, 219
 - long-term properties, 219–24
 - compressive strength, 219–21
 - creep and drying shrinkage, 221–2
 - sulphate resistance, 222–4
 - sulphuric acid resistance, 224
 - mean compressive strength and unit-weight, 220
 - mixture design, production, and curing, 213–16
 - curing, 215–16
 - mixture design, 213–14
 - production, 215
 - mixture proportions, 214
 - mixture proportions tested in hydrocarbon fire, 329
 - modulus of elasticity in compression, 218
 - short-term properties, 216–19
 - behaviour in compression, 216–18
 - indirect tensile strength, 218–19
 - unit-weight, 219
 - stress-strain relation in compression, 217
- Geopolymer conferences, 2
- geopolymer kinetic phenomena, 123
- geopolymeric binders
 - calcination operations influence in mine waste reactivity, 268–71
 - compressive strength
 - according to curing time, 277
 - of alkali activated mine waste mud mortars, 271
 - relationship with modulus of elasticity, 282
 - vs $\text{H}_2\text{O}/\text{Na}_2\text{O}$ molar ratio, 276
 - vs NaOH concentration, 273–4
 - durability and environmental performance, 286–9
 - abrasion resistance, 286–7
 - abrasion resistance with Los Angeles test, 287
 - acid resistance, 287–8
 - contaminant concentration in wastewater, 289
 - environmental assessment, 288–9
 - water quality according to Portuguese Decree 236/98, 290
 - weight loss after acid attack, 288
 - future research trends, 289, 291
 - physical and mechanical properties, 276–86
 - adhesion characterisation, 283–6
 - bond strength coefficient of variation, 285
 - capillary water absorption coefficients, 280
 - modulus elasticity vs molar ratio, 282
 - setting time, 278
 - slant shear test results, 284
 - slant specimen with monolithic failure, 283
 - specimens with adhesive failure, 285
 - static modulus of elasticity, 281
 - unrestrained shrinkage, 279–80
 - water absorption, 280
 - workability, 276–8

- strength gain and mix design parameters, 271–5
 - calcium hydroxide and sodium hydroxide concentration, 271–3, 275
 - H₂O/Na₂O molar ratio, 275
 - mortar composition (C105–C116), 272
 - mortar composition (C126–C128), 278
- unrestrained shrinkage, 279
- utilisation of mining wastes in production, 267–91
- geopolymerisation, 3, 38, 43, 60, 216, 223
 - kinetics, 118–33
- geopolymers, 1–7
 - accelerated ageing, 139–64
 - crystallisation during ageing of gels, 141–2
 - crystallisation during synthesis of gels, 140–1
 - geopolymers synthesised from fly ash, 153–63
 - geopolymers synthesised from metakaolin, 145–53
 - tests, 142–4
- activating solutions, 50–66
 - alkali hydroxide solutions, 51–6
 - alkali silicate solutions, 56–62, 64
 - other activators, 64–6
- applications
 - fire protection, 6
 - host matrix in waste encapsulation, 6
 - low-cost ceramic, 6
 - reduced CO₂ construction material, 6
- cement thermal expansion, 323
- chemical durability, 167–90
 - acid attack, 172–6
 - alkali silica reaction, 180–1, 183
 - frost attack, 189–90
 - general aspects, 167–8
 - high temperature and fire resistance, 183–9
 - resistance to corrosion of steel reinforcement, 176–9, 180
 - sulphate attack and sea water attack resistance, 168–71
- commercialisation for construction, 379–400
 - addressing standards and regulations framework, 385–90
 - alkaline activation, 380–1
 - cement market analysis, 390–1
 - effect of climate change and carbon trading on opportunities, 393–8
 - opportunities for alkali activated materials, 398–9
 - reasons for not commercialising AAM technology, 381–5
- compressive strength
 - addition of silica sand or CaO, 352
 - fly ash/red mud addition, 353
 - glass content, 354
 - immersed in various solutions, 358
 - paste composition, 355
 - pozzolan or kaolinite addition, 351
 - pre-curing period, 356
 - subjected to high temperature heating, 359
 - vs addition of kaolinite or metakaolinite, 351
 - vs temperature and heating time, 355
 - vs temperature when kaolinite or metakaolinite is added, 350
- conclusions, 6–7
- durability studies, 356–59
- engineering properties of geopolymer concrete, 211–25
 - geopolymer concrete, 212
 - long-term properties, 219–24
 - mixture design, production, and curing, 213–16
 - short-term properties, 216–19
- factors affecting compressive strength, 347–56
 - additives, 349–53
 - alkali hydroxide/alkali silicate concentration, 347–8
 - paste composition, 353–4
 - thermal treatment, 354–6
- fly ash
 - nanosstructure/microstructure, 89–114
- history of technology, 1–3
- immersed in various solutions
 - conductivity vs time evolution, 358
 - Eh (mV) vs time evolution, 357
 - pH vs time evolution, 357
- immobilisation of toxic wastes, 421–36
 - main group elements, 424–29
 - other wastes, 435–6
 - transition metals, 430–5
- life-cycle analysis, 194–208
 - assessment, 195–8

- comparison of geopolymers to other product systems, 202–8
- geopolymers and utilisation of secondary resources, 208–9
- influence of composition on environmental impacts, 198–200
- production influence on environmental impacts, 200–2
- lithium geopolymer precursor MAS NMR spectra, 310
- low-calcium slags for strength and durability improvement, 343–71
 - backscattered image of slag-glass geopolymer, 364
 - binder element spectrum, 367
 - composition of slag-kaolinite geopolymers, 354
 - elemental mapping of slag-glass geopolymers, 365
 - experimental synthesis conditions, 360
 - FTIR spectra of slag and geopolymers T1, T2, T3 and T4, 367
 - glass grains element spectrum, 366
 - mineralogical studies, 360–69
 - prospects for industrial application, 369
 - slag grains element spectrum, 366
 - TGA curves for geopolymers T1, T2, T3 and T4, 368
- materials and methodology, 345–7
 - chemical analysis of raw material and additives, 345
 - XRD pattern of slag, 346
- metakaolin
 - nanostructure/microstructure, 72–85
- mineralogical studies, 360–69
 - FTIR, 365–68
 - SEM, 362–5
 - TGA, 368–9
 - XRD, 360–2
- Na-, Na + K, and K-activated, thermal shrinkage, 320
- non-thermally activated clays in production, 294–312
 - 1:1 layer-lattice aluminosilicate minerals dehydroxylation, 296, 298
 - 2:1 layer-lattice aluminosilicate minerals dehydroxylation, 299
 - methods of reproducing the effects of thermal dehydroxylation, 302, 304–8
 - other formation methods of aluminosilicate geopolymers, 308–11
 - reactions of thermally dehydroxylated clays with alkali, 300–2
- nuclear waste immobilisation, 401–16
 - cementitious LLW/ILW waste forms, 405–15
 - future trends, 415
 - nuclear waste around the world, 401–4
- precursor design, 37–45
 - aluminium availability, 42–3
 - designing one-part geopolymer cements, 44–5
 - fly ash, 39–42
 - future cement industry, 45
 - metallurgical slags, 38
- prepared from undehydroxylated 2:1 layer-lattice aluminosilicate
 - 11.7T ²⁷Al MAS NMR, 307
 - 11.7T ²⁹Si MAS NMR, 307
 - XRD powder pattern, 307
- producing fire- and heat-resistant, 227–63
 - alkaline cements phase composition after curing, 229–50
 - experience of application, 257–61
 - mix proportion, phase composition and properties, 250–7
- science, 4–5
- slag-based geopolymers compressive strength evolution
 - vs % w/w addition of Na₂SiO₃, 349
 - vs alkali hydroxide concentration, 348
 - vs KOH concentration, 349
- synthesis kinetics
 - calorimetry, 125–6
 - chemical steps involved in binder formation, 119
 - diffraction techniques, 127–9
 - FTIR spectra of geopolymer development, 121
 - microscopy, 130
 - modelling, 130–2, 133
 - nuclear magnetic resonance, 129–30
 - rheology, 126–7
 - in situ* infrared spectroscopy, 119–25
 - synthesis kinetics, 118–33

- synthesised from starting materials
 - subjected to various pretreatments
 - 11.7T²⁷Al MAS NMR spectra, 303
 - XRD powder patterns, 301
- terminology, 3–4
- thermal properties, 315–39
 - fire resistance, 327–30
 - high temperature applications, 338–9
 - mechanical strength evolution, 330–3
 - microstructural changes, 335–38
 - phase changes at elevated temperatures, 333–5
 - thermal expansion, 316–23
 - thermoanalysis, 324–5
 - thermophysical properties, 326
- XRD patterns
 - geopolymers P80, P200 and P800, 362
 - geopolymers T1, T2, T3 and T4, 360
 - glass-kaolinite and glass geopolymers, 363
 - see also* specific geopolymers
- GGBS, *see* ground granulated blast furnace slag
- glass, 345, 346
- glass chemistry, 41–2
- glass-kaolinite, 362
- global warming potential, 196
- Golden Bay Cement, 383
- granite aggregates, 323
- ground granulated blast furnace slag, 38, 154, 158
 - strength development profiles of geopolymer mortars, 154
- gunnite, 339
- GWP, *see* global warming potential
- gypsum, 171, 223
- halloysite, 305, 309
 - chemical pre-treatment, 306–8
 - acid treatment, 306–8
 - alkali treatment, 308
 - dehydroxylation, 298
 - effect of various pre-treatments, 305
 - powder pattern of dehydroxylated halloysite, 298
- Hanna EC215 conductivity meter, 347
- hazardous wastes, immobilisation by geopolymers, 421–36
 - extraction from silicate-activated fly ash geopolymers of Pb, 425
 - leaching of Cd²⁺ from fly ash-based geopolymer matrices, 435
 - leaching of Cr into deionised water, 433
- main group elements, 424–29
 - arsenic, 426–7
 - boron, 427–28
 - caesium and strontium, 428–9
 - lead, 424, 426
 - other main-group elements, 429
- other wastes, 435–6
- periodic table of elements bound to geopolymers, 423
- transition metals, 430–5
 - cadmium, 434
 - chromium, 431–2
 - copper, 430
 - other transition metals, 435
 - zinc, 432–4
- HDPE, *see* high-density polyethylene
- heat curing
 - effects on environmental impact indicators, 202
 - effects on environmental impact of geopolymer production, 202
- hematite, 235, 236, 325, 335, 361, 370
- herschelite, 142, 148, 231, 232
- high level waste, 401
- high-density polyethylene, 206–8
- high-energy grinding, 304–6
- HLW, *see* high level waste
- hot plate test method, 326
- hydrocalumite, 431
- hydrocarbon fire, 328–9
- hydroceramics, 80, 429
- hydroxylation, 93
- hydroxysodalite, 148, 160, 186, 231, 360, 361
- Idaho National Laboratory, 412
- illite, 362
- ILW, *see* intermediate level waste
- in situ* infrared spectroscopy, 119–25
- incongruent dissolution, 407
- 'induction period,' 121
- inorganic polymer cements
 - and fly ash chemistry, 15–33
- Instron servomechanical machine, 186
- intermediate level waste, 402
- International Atomic Energy Authority, 404, 410
- International Energy Agency, 390, 391
- inter-particle speciation, 20–1
- intra-particle speciation, 21
- IPCs, *see* inorganic polymer cements

- ISO 834, 189, 329
 ISO standards 14040 ff, 195
 isothermal conduction calorimetry, 125
- JEOL JSM-5400 scanning electron microscope, 347
Journal of Materials Science, 381
- kaliophilite, 319, 334
 kalsilite, 183
 kaolinite, 73, 296, 345, 349, 360, 362, 429
 kaolinite dehydroxylate, *see* metakaolinite
 KBr pellet technique, 347
 K:Ca ratio, 364
 kinetic model, 61
 K-PSS, 172
- labradorite, 249
 LARCO S.A Larymna ferronickel plant, 345
 leaching, 407
 lead, 424, 426
 leucite, 183, 249, 319, 334
 life-cycle analysis, of geopolymers, 194–209, 393
 - assessment, 195–8
 - database, 197
 - impact assessment method, 198
 - methodology, 195–7
 - utilised inventories with data source and quality, 198
 - comparison of geopolymers to other product systems, 202–8
 - geopolymer coating vs HDPE liner systems in sewage sludge pipes, 206–8
 - geopolymer vs cement concrete, 203–6
 - comparison of mass balances and GWP results, 200
 - composition of geopolymer and cement concrete, 205
 - effects of heat curing
 - environmental impact indicators, 202
 - environmental impact of geopolymer production, 202
 - framework according to ISO Standard 14040 series, 196
 - geopolymers and utilisation of secondary resources, 208–9
 - impact categories, 197
 - influence on environmental impacts
 - geopolymer composition, 198–200
 - geopolymer production, 200–2
 - results
 - geopolymers and cement concrete, 205
 - geopolymers coating and HDPE lining, 207
 - steps, 195–7
 - goal and scope, 196
 - impact assessment, 196–7
 - interpretation, 197
 - inventory analysis, 196
 - system boundaries
 - for comparison of different geopolymer composition, 199
 - for comparison of geopolymer coating and HDPE lining, 207
 - for comparison of geopolymer concrete and cement concrete production, 205
 - for identification of relevant production processes, 201
- lime, 335
 Linde A, 96
 lithium hydroxide, 53
 LLW, *see* low level waste
 Lone Star, 382
 Los Angeles abrasion apparatus, 286
 low level waste, 402
 low-calcium slags, for geopolymer strength and durability improvement, 343–71
 Lowenstein rule, 107
 low-temperature inorganic polymer glass, 126
- maghemite, 360, 361
 Magic Angle Spinning Nuclear Magnetic Resonance, 428
 magnesium silicates, 228
 magnetite, 345, 360, 361
 Master Builders, 383
 Materials Data JADE 6.0 software, 268
 mercury intrusion porosimetry, 336
 metakaolin, 2, 4–5
 - compressive strength during ageing at 23°C, 145
 - compressive strength during ageing at 95°C, 146
 - correlation between compressive strength and Na-P1 content, 148

- density and thermal conductivity, 326
- effect of ageing temperature and time on
 - zeolite crystallisation, 152
- fractional elemental extractions in PCT-B tests, 409
- geopolymer structure, 72–85
 - calcium, 84
 - compressive strengths, 82
 - geopolymer formation, 75–6
 - geopolymerisation, 75–6
 - layered structure of kaolinite, 74
 - Metastar x-ray analysis, 74
 - microstructure, 81–2
 - nanostructure, 76–81
 - SEM images of microstructure of synthesized geopolymers, 83
- mechanical strength evolution, 332
- mercury intrusion porosimetry data, 338
- microstructure, 149
- restructuring of geopolymer gel, 149
- TGA-DTA curves, 324
- X-ray diffraction patterns, 147
- metakaolinite, 294, 296, 345, 349, 361
- metallurgical slags, 38
- Metastar 402, 74
- Mg-K-phosphate mixtures, 414
- microscopy, 130
- microstructure
 - fly ash, 111–14
 - alkali activation, 113
 - SEM images of original morphology, 111
 - zeolite SEM images, 112
 - metakaolin, 81–2
- mine wastes
 - calcination effects on XRD diffraction, 270
 - calcination operation influence on reactivity, 268–71
 - chemical composition and specific surface, 269
 - compressive strength according to thermal treatment, 270
 - and concrete substrate interfacial transition zone, 286
 - for geopolymeric binder production, 267–91
 - XRD patterns of mine wastes treated at different temperatures, 269
- minimum cement content, 385
- mining wastes, *see* mine wastes
- modulus of elasticity, 217–18
- montmorillonite, 299
- mordenite, 231
- MTS 1600 load frame, 346
- mullite, 20, 243, 271, 302, 334
- muscovite, 268, 299
- Na:Al:Si ratios, 412
- nanostructures
 - metakaolin, 76–81
 - nuclear magnetic resonance, 76–8
 - structural models, 79–81
 - X-ray pair distribution function analysis, 78–9
- N-A-S-H gel, *see* sodium aluminosilicate gel
- National Allocation Plans, 395
- natrolite, 362
- natural clinoptilolite zeolite, 430
- nepheline, 186, 228, 229, 231, 319, 334, 335
- nickel, 435
- nitrogen, 324
 - adsorption/desorption, 336
- NMR spectroscopy, 426
- Nordtest NT Fire 046, 328
- nuclear magnetic resonance, 76–8, 129–30, 316
 - ²⁹Si NMR spectra of geopolymers, 77
- nuclear waste
 - around the world, 401–4
 - cementitious LLW/ILW waste forms, 405–15
 - actual waste immobilisation in geopolymers, 413–14
 - alternate low-temperature products, 414–15
 - aqueous dissolution behaviour, 407–10
 - comparison with OPC, 412–13
 - conformance with regulatory tests, 410–11
 - effect of anions, 411–12
 - factors to be considered, 407
 - fire resistance, 413
 - flow sheet for disposal, 406
 - freeze-thaw behaviour, 413
 - key properties of candidate waste forms for immobilisation, 415
 - radiolytic hydrogen, 413
 - strategies for immobilisation, 405
 - supercompaction process for immobilisation, 406

- drums containing LLW stored at ANSTO, 403
- half-lives and decay modes of fission products and actinides, 402
- immobilisation by geopolymers, 401–16
 - advantages, 415
 - future trends, 401–16
- olivine group, 361
- 'Ongoing gel rearrangement and crystallisation,' 129
- opal, 384
- OPC, *see* Portland cements
- orthoclase, 231, 362
- Ostwald's rule, 99, 141, 148, 241
- OTIS company, 261
- Oxford energy dispersive X-ray spectrometer, 347
- paint sludges, 426
- PCT-B, 410, 411
- Perkin Elmer Thermogravimetric Analyser TGA 6, 347
- perlite, 261
- phase equilibria, and solubility, 56–8
- phenols, 436
- philipsite, 109, 142, 153, 309
- pirssonite, 362
- plagioclases, 231
- planetary ball mill, 304–5
- plombierite, 157
- Poisson's ratio, 218
- pollucite, 78–9, 334
- polycondensation, 93
- polymerisation, 92–6
 - coagulation–condensation, 93–4
 - condensation–crystallisation, 94–6
 - conceptual model for geopolymerisation, 95
 - destruction–coagulation, 93
- Portland cement-based system, 38
- Portland cements, 127, 140, 195, 204, 205, 405, 426, 427
 - alkali-silica reaction-induced expansion, 181
 - carbon dioxide emission, 211
 - compared with geopolymer concrete, 211–25
 - compressive strength evolution
 - exposed to 5% sodium and magnesium sulphate solutions, 169
 - exposed to acid solutions, 173
 - concrete mechanical properties
 - degradation, 333
 - flexural and compressive strengths, 187
 - mechanical strength, 175
 - mixture proportions tested in hydrocarbon fire, 329
 - thermal expansion, 323
 - variation in i_{corr} vs time, 179
 - variation in residual bending and compressive strength in cold samples, 185
- Portuguese Decree 236/98, 289
- Portuguese kaolin, 302
- Portuguese Standard LNEC E398-1993, 279
- potassium aluminosilicate system, 429
- potassium chabazite, 153
- potassium hydroxide, 55
- potassium sialate, 183
- pozzolan, 345, 350
- precipitation, 94–5
- pre-curing, 235
- price instrument, 394
- 'pseudo-plastic' behaviour, 188
- Pyramont, 382–3
- pyrophyllite, 299, 302, 306
- quantity instrument, 394
- quartz, 241, 243, 268, 321, 323, 335, 345, 360, 361, 362
- quartzite, 384
- radium, 429
- red mud, 345, 346, 352
- reinforced concrete structures, 176
- Réunion Internationale des Laboratoires et Experts des Matériaux, 388
- rheology, 126–7
- Rietveld refinement, 333
- Roman *opus caementicium*, 141
- rubidium hydroxide, 55
- scanning electron microscopy, 336, 362–5
- selenium, 429
- SEM, *see* scanning electron microscopy
- shotcrete, 339
- Si MAS NMR, 129
- SIAL, 413
- Si:Al ratio, 147, 174, 315, 318, 321, 324, 334, 363, 408
- sialate bond, 4

- Siemens D500 diffractometer, 347
 silica, 345
 silica sand, 345, 351
 silicon, 97–9
 silicon carbide, 261
 silicon oxide, 213
 Siloxo Pty. Ltd., 383
 Si-O-Al bonds, 174, 359
 Si-O-T bonds, 120
 Slovak power reactors, 414
 sodium, 107–11
 sodium aluminate, 412
 sodium aluminium oxide, 361
 sodium aluminium silicate carbonate, 308
 sodium aluminosilicate, 180, 184
 sodium aluminosilicate gel, 96–9, 101–11,
 162, 229, 231
 role of aluminium, 101–7
²⁷Al MAS-NMR spectra of ash pastes,
 104
 central component of ²⁷Al MAS-NMR
 spectra of fly ash pastes, 105–6
 mechanical strength, 103
 role of silicon in gel structure, 97–9, 101
 nanostructural model, 102
²⁹Si MAS-NMR spectra of type F fly
 ash, 98
²⁹Si NMR spectra of alkaline
 solutions, 100
 role of sodium, 107–11
 central component of 180-day ²³Na
 MAS NMR spectra for ash pastes,
 110
 central component of ²³Na MAS
 NMR spectra for ash pastes, 108
 soluble sodium variation, 109
 sodium aluminosilicate system, 429
 sodium arsenate, 427
 sodium carbonate, 232
 sodium chabazite, 148, 151, 157
 sodium hydroxide, 53–5, 122, 278, 412
 phase diagram, 54
 solids, 213
 solution, 212
 sodium nitrate, 412
 sodium nitrite, 412
 sodium P1, 151
 sodium silicate solution, 212, 213
 soil-cement, 380
 sol-gel process, 92
 ‘Solidification and hardening,’ 128
 solidification/stabilisation, 422
 solid-state magic angle, 408
 solubility, and phase equilibria, 56–8
 steam-curing, 216
 strained quartz crystals, 384
 strontium, 428–30
 super plasticiser, 204, 212, 213, 215, 278
 supplementary cementitious materials, 387
 synthesis kinetics, of geopolymers, 118–33
 apparatus used for EDXRD experiments,
 128
 calorimetry, 125–6
 changes in intensity at 960cm⁻¹, 124
 diffraction techniques, 127–9
 experimental EDXRD vs model
 predictions, 132
 FTIR spectra, 121
 kinetic analysis sample activated
 with different concentrations of
 NaOH, 123
 with 6M NaOH, 122
 microscopy, 130
 modelling, 130–1, 133
 NaOH concentration ratio and
 geopolymer gel growth rate,
 118–33
 nuclear magnetic resonance, 129–30
 potassium silicate/metakaolin geopolymer
 system EDXRD data, 129
 quasi-isothermal DSC data, 126
 reaction process described by reaction
 kinetic model, 131
 rheology, 126–7
in situ infrared spectroscopy, 119–25
 TCLP test, *see* Toxicity Characteristic
 Leaching Procedure
 TGA, *see* thermogravimetric analysis
 thermal expansion, of geopolymers, 316–23
 common coarse aggregates, 323
 comparison with ordinary Portland
 cement, 322
 fly ash geopolymers, 321–2
 influencing factors, 319–21
 alkali activator, 320
 compositional ratio, 321
 source material type, 321
 water content, 319–20
 metakaolin geopolymers, 321
 thermal properties, of geopolymers, 315–39
 fire resistance, 327–30

- concrete slabs tested for hydrocarbon fire exposure, 330
- fire test results, 329–30
- Portland cement and geopolymer concrete mixture tested in hydrocarbon fire, 329
- specimens after fire test, 331
- standard fire curves, 327–29
- temperature vs time relationship of standard fire, 328
- time vs temperature curve of typical room fire, 327
- high temperature applications, 338–9
- mechanical strength evolution, 330–3
 - comparison to ordinary Portland cement, 332–3
- microstructural changes, 335–38
 - pore structure evolution, 336–38
- phase changes at elevated temperatures, 333–5
 - geopolymer paste formation and destruction, 334–5
 - phases formed from secondary material, 335
- shrinkage/expansion characteristics of geopolymers, 317
- TGA/DTA, 324–5
- thermal conductivity, 326
- thermal expansion, 316–23
 - comparison with ordinary Portland cement, 322
 - fly ash geopolymers, 321–2
 - geopolymer concrete, 323
 - influencing factors, 319–1
 - metakaolin geopolymers, 321
- thermoanalysis, 324–5
- thermophysical properties, 326
- thermodynamics
- thermogravimetric analysis, 316, 324, 368–9
- thermonatrite, 362
- titanium, 21
- tobermorite, 157
- tonnes CO₂ equivalent, 393
- Toxicity Characteristic Leaching Procedure test, 404, 426
- transmission electron microscope, 336
- tridymite, 335, 345, 362
- trona, 232, 361, 362
- tungsten mine waste mud, 278, 229
- uranium, 429
- V.D. Glukhovskiy Institute, 261
- vermiculite, 261
- vibratory mill, 304–6
- Vicat needle, 278, 289
- Vicat penetration test, 280
- wastewater treatment sludges, 426
- water-to-cement ratio, 214, 316, 386
- WINFIT software, 104–5
- XANES, 426
- X-ray absorption spectroscopy, 426
- X-ray diffraction, 333, 360–2
- X-ray pair distribution function analysis, 78–9
 - pollucite vs caesium aluminosilicate pair distribution function, 79
- XRD, *see* X-ray diffraction
- Young's modulus, 318, 320, 330
- Zeobond, 389
- zeolite, 80
 - see also* specific zeolites
- zeolite Na-P1, 148
- zeolite P, 109
- zeolite precursor, 141, 229, 231, 238
- zeolite synthesis, 123
- zeolites, *see* specific mineral species
- zinc, 432–4
- zirconia, 412
- Zn-O-Si bonds, 432