Index

a

accelerated ageing 475
adherend–adhesive interface 246
adhesion-inhibiting effect 434
adhesive–adherend phase boundary
  polymer adhesives on impenetrable solids 28–32
  polymerisation on solids 32–33
adhesive interaction
  chemical adhesion mechanisms 11–12
  electrostatic component of adhesion 21
  mechanical interlocking 27
  microscopic adhesion mechanisms 26–27
  physical intermolecular forces 4–5
adhesive joints
  chemical ageing, with steel S235 335–336
  corrosive attack on the corundum blasted steel 333–335
  mechanical modulus 338–346
  water diffusion 331
adhesively bonded timber–concrete composites
  alkaline environment 450
  hygro-thermal impact 450–452
  time-dependent mechanical strains 450
ageing processes 170, 265, 309
aliphatic amine hardener 266
applied ageing conditions 504
Arrhenius-type equation 276
artificial ageing 271–273, 508

b

basic epoxy (EP) adhesive 376
  artificial ageing conditions 271
  chemical ageing processes 288
  chemistry of 268
  commercial epoxy adhesives 300–304
  DGEBA 266, 267
  DGEPG 266, 267
  dog bone samples 268
  metal substrates 268
  oxirane rings 268
  polyether amine 266, 267
  pre-treated electro-galvanised steel
  water diffusion 273
Berkovich indenter 111
bi-linear traction-separation law 146
bi-molecular interaction energy 5, 6
bisphenol A diglycidyl ether (DGEBA) 376
bondline corrosion 347, 505, 512
Brønstedt-like acid–base mechanism 17
Brillouin frequency shifts (BFS) 123
Brillouin spectroscopy 82, 83
brittle crack propagation 398
buried layers 80
butt joint test 147

c

carbon-fibre-reinforced-plastics (CFRP) 430, 444, 504

Adhesive Joints: Ageing and Durability of Epoxies and Polyurethanes,
First Edition. Edited by Wulff Possart and Markus Brede.

Cauchy–Green tensor 55
cavitation bubbles 431–432
chemical adhesion mechanisms
  chemical reactions 14–16
  electron band structure 13–14
  MO theory 12–13
  reactive epoxies on inorganic solids 16–18
  reactive polyurethanes on inorganic solids 18–21
chemical ageing 174, 175, 311, 361–362, 512
  metal joints bonded 291–297
  metal substrates corrosion 288–291
  metal surface, role of 298–299
  vs. physical plasticisation 299–300
  processes 505
cleaning behaviour, power ultrasound 433
  surface free energy contamination 434–436
  ultrasound amplitude influence 437
cohesive zone model (CZM) 146, 507
  automotive crash simulation 405
  closed-form solutions of diffusion 419–420
  commercial finite element codes 146
  computational efficiency 146
  damage behaviour 409–411
  elastic and an elastic-plastic solid 231
  finite element codes 406
  mixed mode energy release rate 152
  numerical accuracy 146
  plastic zone size 154
  stress tensor 147
  three-dimensional adhesive material model 405
  tri-linear traction separation law 149
  validation
    tensile tests of butt joints 411–413
    viscoelatic material model 413–416
  viscoelasticity 407–409
competitive adsorption 30
composite beams
  concrete–concrete connection 474
  lap shear specimens ageing 475
  large scale 481–487
  materials 472
  steel–concrete connection 474
  steel–steel connection 473
concrete
  material model of 454
  material parameters 456
condensed phases 9–11
continuous relaxation test 197
continuum mechanics
  phenomenological approach 205
  kinematics 206–211
continuum model for the electric double layer 23–26
controlled-mixed-mode bending test (CMMB-test) 151
conventional constitutive models 45
crack propagation 381, 387
crack tip plastic zone 155
Crank–Nicolson scheme 356
creep tests 189, 190
critical energy release rate 139
  ductile type 383
  inelastic deformation 377, 378, 379, 391
  TDCB samples 376
  thickness of bond 381
  viscoelasticity 384, 385
  water concentration 390, 391
cross-linking adhesives 43
curing processes
  material parameter evolutions
    bulk modulus 67
    degree of cure 68–69
    first Lamé parameter 67
    Poisson's ratio 67
    relaxation times 68

second Lamé parameter 66
shear modulus 66
shrinkage 68
one-dimensional linear viscoelastic, small strains 45–52
polymer curing 44–45
three-dimensional curing, large strains
elastic Neo-Hookean curing model 58–59
elastic simulation framework 55–58
thermodynamic consistency 55–58
viscoelastic Neo-Hookean curing model 59–63
viscoelastic simulation framework 59
viscoelastic glassy polymers 44
curing shrinkage 44, 64–65, 68–75

d

damage behaviour, viscoelasticity 409–411
damage evolution model 363–364
Debye bi-molecular induction energy 7
deformation inhomogeneity 502
deformation zone 378
density measurements 188, 189
differential scanning calorimetry (DSC) 270, 272
diffusion current densities 22
diffusion models 35, 273, 385
diffusion of tracers 223–225
di-functional epoxy resin 266
diglycidyl ether of bisphenol A (DGEBA) 266, 267
2,4′-diphenyl methylene diisocyanate (2,4′-MDI) 311
4,4′-diphenylmethylene diamine 322
dispersive interaction 7
double cantilever beam (DCB) 147, 232
Drucker–Prager equivalent stress 381
ductile crack propagation 398
Dugdale–Barenblatt model 145
dynamic induction energy 7
dynamic mechanical analysis (DMA) 186

e

elastic interphases 97–101
elasticity 279, 366–367
elastic Neo-Hookean curing model 58–59
elastic simulation framework 55–58
elastoplastic interphases 101–106
electric double layer (EDL) 22–23
built of mobile electrons 25
electrochemical impedance spectroscopy (EIS) 439–442
electron band structure 13–14
electronic polarizability 6
electrostatic component of adhesion
continuum model for the electric double layer 23–26
mobile charge carriers 22–23
end-loaded shear joint (ELSJ) 149
end-notch-flexure sample (ENF) 149
energy dissipation 143–145
epoxy adhesive joints 502
brittle type 394
Fick's diffusion equation 394
fracture surface 398
load *vs*. displacement curves 396
material model 455, 457
thixotropically modified 395, 396
ultrasound-supported application 396
epoxy–ceramics composite 69–75
epoxy network 268
epoxy–zinc galvanised steel joints 504
Euler-backward integration 54
extended finite element method (XFEM) 260
extrinsic ageing 170

f

FE-simulations of adhesive layers
  curing process 106
  elastic interphases 97–101
  elastoplastic interphases 101–106
  mesh dependency study 92–97
fibre reinforced plastics (FRP) 135
Fick's diffusion equation 274, 394
Fick's law of diffusion 356
finite element simulation of diffusion 418–419
focused ion beam (FIB) 86
Fourier transformed infrared spectroscopy (FT-IR) 184
fracture, adhesive joints 503
fracture process zone 231
fracture surface energy 140, 399
fresh and aged adhesive joints
  shear tests 280–286
  tensile tests, dry epoxy bulk samples 279–280

g

gel point 44
glass transition temperature 379

h

Hamaker constant 9
hard-soft acid–base principle (HSAB principle) 15
Helmholtz free energy 44
hexamethylene diisocyanate (HDI) 18
high-performance concrete (HPC) 460
Hooke's law 124
hydrostatic stress 383
hygro-thermal impact, timber–concrete composites
  deflection of full-scale specimens 465–467
  full-scale specimens under natural climatic conditions 463–464
  material models 453–454
  mechanical material properties 454–457
  moisture transport in wood 457–459
  rheological behaviour 453
  small-scale samples under artificial climatic conditions 460–463
  wood moisture content 464–465

i

incompressible Neo-Hooke material 330
inductive intermolecular interaction 7
interphase formation 225–226, 502
Irwin–Kies equation 147, 230, 242, 383
isotropic electric conductivity 22

k

kinematics 206–211

l

Langmuir-type of diffusion 356–358
lap shear specimens ageing
  accelerated ageing 475
  outdoor weathering 475
large scale composite beams
  4-point bending test 481, 482
  fracture appearance after testing 483
  plastic resistance moment 485
Lennard-Jones potential 8
Lewis' famous acid–base concept 15
life span prediction 501, 507, 511
Lifshitz concept 9
linear-elastic fracture mechanics 503
  crack tips 136
  displacement fields 137
  local stress 137
  opening mode 137
  plastic zone sizes 136
  stress-intensity factor 137
London interaction 7

m

Maxwell elements 509
Maxwell spring 51, 52

Maxwell model 408
mechanical ageing 180
mechanical interlocking 27
mechanical interphases
  buried layers 80
  concept 79
  definition 79
  effects 81
  existence and properties 81
  experimental approaches 83
  high-resolution shear testing, SCM
    diverse deformation behaviour 90
    experimental setup 84
    inelastic deformation 90
    micro shear test method 90
    shear deformation profiles 88
    specimen preparation 84–88
  numerical modelling and simulation 82
methylene diphenyl diisocyanate (MDI) 18
microscopic adhesion mechanisms 4, 26
Mises equivalent stress 380
mobile charge carriers 22–23
modulated differential scanning calorimetry (MDSC) 436
moisture transport in wood 457–459
molecular orbital theory (MO theory) 12–13

n
nanoindentation (NI)
  FE-simulations 114
  information volumes 111
  OP method 110, 112, 113
  Young's modulus 111
Neo-Hooke material model 92, 384, 413
Neumann boundary conditions 356, 364
Newton–Raphson method 54, 57

o
Oliver and Pharr (OP) analysis method 110
  mechanical characterisations 110
  stiffness and hardness 113
outdoor weathering 507
  lap shear specimens 475
oxidation 176, 177
oxygen absorption 184, 185

p
permanent dipole moments 6
photoelasticity 69–73
photoelastic stress 71
physical ageing 172, 173, 309, 330–331, 506
physical intermolecular forces
  bi-molecular interactions 5–8
  condensed phases 9–11
physical plasticisation effect 299–300
Piola–Kirchhoff stress 64
Poisson's ratio 382
polycarbonate 198
polychloroprene rubber (elastomer) 198
polyether amine 266, 267
polyetherpolyol-cured PU adhesive 313
polyether polyurethanes 311
polyetheryol-diisocyanate chemistry 377
polymer adhesives on impenetrable solids 28–32
polymer ageing
  caloric investigations 182
  chemical ageing 174, 175
  chemical and physical 169
  continuous and intermittent testing 196
  continuous relaxation test 197
  crystallisation 192, 193
  density measurements 188, 189
  diffusion phenomena 171
  diffusion process 198
  dynamic mechanical analysis 186
  glass transition temperature 191
  heterogeneous *vs.* homogeneous ageing processes 171
  intermittent relaxation tests 196

polymer ageing (*contd.*)
intrinsic and extrinsic influences 170
liquid state *vs.* solid state kinetics 171
macromolecular structure and physical behaviour 199
mechanical ageing 180
medical applications 169
molecular chains 192
network degradation and network reformation 196
oxidation 176, 177
oxygen absorption 184, 185
physical ageing 172, 173
relaxation and creep tests 189, 190, 194
rigid amorphous phase 192
tensile, compression and shear testing 187
thermogravimetry 183
thermomechanical analysis 185
polymer curing 44–45
polymerisation 32–33, 502
polypropylene ether alcohol fragments 329
poly(propylene glycol) diglycidyl ether (DGEPG) 266
polyurethane (PU) adhesives 376, 377, 473
adhesive joints 331–333
crack propagation 387
irreversible chemical degradation 390
saturated concentration 386
viscoelasticity 390
artificial ageing conditions 314
bulk samples and steel adhesive joints 314
chemical ageing 311, 315–316
compliant mechanical characteristics 310
DSC and TGA techniques 310
elasticity 366–367
hydrolytic cleavage 311
monomer mix 313
physical ageing 330–331
pyrolysis 312
steric hindrance effects 311
urethane crosslink density 310
viscoelasticity 367–371
power-law criterion 152
power ultrasound process
cavitation 431–432
cleaning behaviour 433
contamination tolerant adhesive application 429–431
reinforced plastics 444–446
ultrasound-assisted primer application 442–444
viscosity changes 432–433
practical adhesion 35–36
preferential monomer/oligomer adsorption 33
primary interphases 502

r

reactive epoxies on inorganic solids 16–18
reactive polyurethanes on inorganic solids 18–21
relaxation tests 189, 190, 194
rigid amorphous phase 192

s

scanning Brillouin microscopy (SBM)
experimental setups 120
sound velocity profiles 123
spatial dependence 124
strain gradients 125
2nd law of Fick diffusion 331
shear resistance 471
shrinkage deformation 64
small scale yielding (SSY) 144
softwood
elastic material parameters 455
hygric and thermal material parameters 455
mechano-sorptive material parameters 456
viscoelastic material parameters 456

S235 steel surfaces 268, 269
static polarizability 6
steel–concrete connection 474
stress birefringence 125
stress-intensity factor 137
substrate corrosion, bondline 505
surface contaminations 430
surface emissivity coefficients 458

t
tapered double cantilever beam (TDCB) tests
  computational approach 232
  dissipation in 230–232
  energy balance estimate 258–259
  finite element simulations 233
  infrared camera
    aim and measurement principle 248–249
    experimental observations 249–254
    heat generated 256–258
    thermo-elastic effect 254–256
  limitations 259–262
  plastic work, finite element simulation
    crack growth 238
    cross-head velocity 244
    elastic-plastic material models 235
    fracture mechanics 238
    inhomogeneous distribution 237
    plastic strain energy 238–244
tapered ENF samples (TENF) samples 149
tensile, compression and shear testing 187
thermo-elastic effect 254
thermogravimetry 183
thermomechanical analysis (TMA) 185
thermo-mechanical continuum model 503
thermooxidative ageing 170
thermoplastic polymers 28
thixotropically modified 395, 396
toluene diisocyanate (TDI) 18
toughened adhesives
  cohesive zone model 145–156
  fracture of joints 145
  micro-structure of 156–161
traction-separation law 146
traditional nanoindentation 111
tri-linear model 146
tri-linear traction-separation law 146, 149

u
ultrasound-assisted cleaning process 444
ultrasound-assisted primer application 442–444

v
virtual crack closure technique (VCCT) 232, 237
virtual interphase 502
viscoelastic components 146
viscoelastic curing model 50, 69, 71
viscoelastic fracture models 381
viscoelastic polymers 34–35
viscoelastic simulation framework 59
viscoelasticity 217–220, 279
  cohesive zone model 407
viscoelasticity, ageing joints
  constitutive equations 214–217
    adhesive water 360–361
    chemical ageing 361–362
    damage evolution model 363–364
    non-linear viscoelastic material behaviour 358
    size effects 362–363
    temperature 359–360
  epoxy adhesive 371–372
  polyurethane adhesive results of 366
  transport processes in adhesives
    Fick's law of diffusion 356

viscoelasticity, ageing joints (*contd.*)
Langmuir-type of diffusion 356–358
viscoelastoplastic (concrete) mechanical laws 507
von Mises elastoplasticity 101

w
water concentration profile 511
water diffusion coefficient 330
wood material model 453
wood moisture content 464–465

x
X-ray photon spectroscopy (XPS) 445

y
Young's modulus 382