# Index

Absolute temperature (degrees Kelvin), 10, 130, 135, 150
Activity (of clays), 7–9, 12, 18
Adsorbed water, 9, 12, 16, 18, 142, 161, 163, 165–6, 171, 225, 228–9
Double layer, 9, 16, 18, 144, 165, 225, 228–9
Aggregates (of soil particles and water), 1. See also Soil structure
Adsorption (uptake) of water and swelling, 30, 33, 120, 175, 199, 234
Aggregates per unit volume of soil, 169
Breakdown, 114, 118, 178, 199–200, 221, 228–9
Creation, 18, 25, 59, 157–8, 167–8, 176, 195
Definition (description), 5, 175
Distortion and deformation, 30, 33, 120, 175, 199, 228, 230, 236–7, 239, 241, 243, 249
Enthalpy of. See Enthalpy
Inter-aggregate bonding, 230, 247
Inter-aggregate voids and intra-aggregate voids. See Voids
Saturated aggregates, 25–6, 31–3, 59, 157, 164, 173, 175
Slippage, 30, 120
Specimen preparation, 59–63, 181
Volume of aggregates per unit volume of soil, 5
Air bubbles. See Bubbles
Air entry value, 14, 37–8, 46–7, 52, 72–3. See also High-air-entry discs
Air pressure, 37–8, 66, 82, 168–9
Air pressure in bubbles, 16
Atmospheric (gauge) pressure, 2, 36, 38, 156–7
Pore air pressure, 9–12, 21, 38, 43, 52, 65, 70–71, 88, 94, 97, 151, 156–8, 163–4, 171–2, 186
Air voids and air voids ratio. See Voids
Air–water interface. See Contractile skin and Surface tension
Aitchison’s stress, 88–9
Amphill clay, 2, 8
Angle of friction
Associated with changes in \( \left( u_a - u_w \right) \), 94
Effective angle of friction, 94
Anisotropy
Anisotropic loading and stress states, 122, 133, 141, 147, 152–6, 158–61, 185
Anisotropic properties and behaviour, 22, 59, 62, 106, 142–4, 203, 213, 224, 227, 235, 237, 251–3
Anisotropic yielding, 87
Stress-induced anisotropy, 31, 117, 123, 245
Area cut by plane, 9, 19–20, 70, 153, 172–3
Area of air voids cut by flat plane, 172
Area of solids cut by flat plane, 19, 173
Area of water voids cut by flat plane, 172
Atmospheric pressure. See Air pressure
Atterberg limits
Liquid limit, 7, 181
Plasticity index, 7, 9, 192
Plastic limit, 7, 14, 181, 189
Average soil skeleton stress tensor, 89
Average volumetric ‘coupling’ stress, 159, 163, 166, 172–3, 180–211, 214–5, 220, 225
Coupling stress and tensor, 172–4, 179
Axis translation
Equilibration time, 35
Null-type axis translation technique, 52
Axi-symmetrical loading, 69, 91. See also Triaxial tests
Barcelona Basic Model (BBM), 107–12, 203, 206, 208, 211
Extended models, 112–23
Belfast Upper Boulder clay, 7–8
Bentonite, 23. See also Montmorillonite and Smectite
Sodium-rich bentonite, 7–8, 191
Bentonite enriched sand (BES), 180, 189–92, 194, 197
Sand-bentonite, 55, 58, 76, 123
Bi-modal structure and pore size distribution. See Soil structure
Bishop’s stress, 88–9, 93, 95–6, 121
Boom clay, 65, 177
Botkin silt, 118
Breakage of particles and aggregates, 199, 228–9. See also Strain and strain-increments: Degradation straining
Bubbles, 33
Air bubbles influence on measurements, 37, 45–7, 52–3, 82, 156
Air bubbles in soils, 15–20, 163–5, 169, 178
Equilibrium bubble radius, 16–17
Nucleation and bubble dynamics (growth and decay), 15–16, 140
Vapour bubbles, 15–20
Calcite, 7
Cam clay model (original and modified), 98–9, 105, 110, 203, 226
Capillarity, 10–11, 14, 24, 35, 50
Capillary tube. See Capillarity
Cathetometer, 79
Cavitation, 15–16, 33, 44–6, 52–3, 71, 74
Chemical potential. See Potentials
Chilled-mirror dew-point devices. See Psychrometers
Cohesion, 101, 200, 226
Cohesionless soils, 95, 226
Cohesive soils, 22, 95, 103, 226
Collapse and collapse compression, 30, 32, 110, 120–1, 129, 139, 141–2, 176–9
Collapsible soils, 3
Colloids, 18
Compaction and compacted soils, 2–4, 6, 22, 24–6, 28–30, 33, 47, 97, 100, 108, 113, 116, 118, 121, 123, 168, 175, 178, 188, 191, 197–8, 203, 205, 210, 243
Dynamic and static compaction, 27, 94, 96–7, 116, 181, 185–6, 189, 198
Proctor and Modified Proctor compaction, 6
Compression (isotropic and one-dimensional) of specimens, 18, 47, 59, 61–2, 69–70, 99–100, 105, 109–10, 116–17, 121, 123, 181, 186, 198–9, 204–5, 210, 230, 232–3, 236, 238, 245, 253. See also Strain and strain-increments
Compression characteristics and behaviour, 6, 25, 65, 69, 101, 128, 200–2, 204–5, 210–11
Compression coefficients, 114
Compression indices, 97
Compression tests and equipment, 24, 71, 189, 245, 253
Isotropic compression, 27, 32, 63, 116, 185, 192, 199–200, 202, 204–5, 210–11, 245
Isotropic normal compression hyperline, 116
Virgin compression, 110
Conjugate stress and volumetric variables. See Conjugate variables
Conjugate variables (conjugate pairings), 4, 135–6, 142–6 (See also Thermodynamics: Conjugate thermodynamic variables)
Conjugate stress and volume variables, 90, 125, 174–5, 179, 181, 183, 194, 215, 223–4, 230, 251
Constant water mass tests, 113, 136, 186, 189–90, 198–9, 205, 245, 249, 253
Constitutive relations
Equations, 87, 89, 97, 176
Modelling (frameworks), 87, 89, 92–3, 97, 107–8, 112–25, 208, 223, 226, 252–3
Contact angle
Of air–mercury interface with wall of capillary, 24
Of air–water interface with wall of capillary, 10
Continuum and continuum mechanics, 92, 173, 225–6
Contractile skin, 9–10, 12, 14–8, 88, 151, 157–8, 171, 173, 178, 229–9. See also Air–water interface, Surface tension and Enthalpy
Critical state characteristics for saturated soil, 103
Critical state framework, 98–107
Critical state line (csl), 14, 99–101
Hvorslev surface, 103
Isotropic normal compression line (iso-ncl), 99–103, 108
One-dimensional normal compression line (1d-ncl), 99–103
Roscoe surface, 103
State boundary surface, 99, 103–4
Unloading and reloading line (url), 102–4
Critical state characteristics, 181, 197–8, 200
Critical state framework, 107–19
Critical state hyperlines, 116
Critical state line (csl), 14, 108–10, 112, 118, 181, 206, 211
Hyperspace, 206
Isotropic normal compression hyperline, 116
Isotropic normal compression line (iso-ncl), 109, 116–8, 123, 125, 181, 203–6, 210–11
One-dimensional normal compression line (1d-ncl), 123, 125
State boundary hypersurface, 116
Unloading and reloading line (url), 109–10, 112
Critical state for saturated soil, 93, 100–1, 103, 105, 216–7, 221, 224
Critical state framework, 93, 98, 101, 124–5
Critical state parameters, 101–2, 128, 216
Critical state soil mechanics, 98–9, 103, 105
Critical state strength, 93, 101, 103, 139, 216–7, 226
Definition of critical state, 100
Critical state parameters, 108–10, 113–9, 217
Critical state soil mechanics, 107
Critical state strength, 108, 113–4, 118, 139, 180–2, 185–7, 190, 192, 194, 198–9, 203, 205–6, 209–10
Crystalline
Crystalline ice, 142
Crystalline water, 9, 161, 163, 165–6
Particles, 7
Swelling, 8–9, 18
Dalton’s divisional law, 142, 161, 163
Degree of saturation (with water), 2, 5, 12, 14, 25, 61, 88–9, 97, 113, 120, 127, 150–1, 165–7, 170–1, 173, 175, 178–9, 184, 200, 208, 221
Density, 24, 32, 61, 142, 174, 179
Bulk density, 6
Dry density, 6, 71, 116, 195
Dry density – water content relationship, 6
Maximum dry density, 6
Of dry aggregated soil, 195
Of soil particles (relative density, specific weight or specific gravity), 6, 32
Of water, 6, 144
Desiccation, 2
Deviator stress, 24, 24, 69, 71, 74, 82, 92, 100–1, 103, 105, 108, 110, 114, 116, 124, 153–6, 180, 182, 190–2, 194, 198, 210–1, 214, 216–7
Components of the deviator stress for unsaturated soil, 215–19, 221, 224, 233–4, 237, 241, 243, 245, 249, 251–2
Diffusion of air, 38, 52, 83
Dilation and rate of, 103, 178, 226–7, 230, 233, 249, 253
Dimensionless model (and dimensionless stress-volume space), 146, 180
Dimensionless variables, 165–6, 181, 198, 203–4, 210–1
Discontinuities
  In behaviour, 176, 178–9, 181, 199–200, 209, 211, 221–2, 241, 243, 245, 249, 253
  In soil structure (fissures, laminations, bedding planes, tension cracks), 6–7, 22, 24–5, 28, 168, 171, 186, 195–6, 209, 236, 241, 245, 252
Dispersed soil structure, 18, 22, 25, 114, 118, 176, 178, 181, 202, 208
Dispersion of energy. See Energy
Dissolved air and gases, 9, 15–7, 73, 83, 144, 161, 163–4, 166, 168, 171, 228
Distinct element method (DEM), 228
Dolomite, 7
Double layer. See Adsorbed water
Dual-energy gamma-ray technique, 23

Effective stress. See Terzaghi’s effective stress
Elastic behaviour, 99, 106–7, 110, 116, 120, 125. See also Elastic energy and Elastic work
  Elastic compression or expansion, 110
  Elastic deformation of particles and aggregates, 120, 228
Elastic solids, 103
Elastic stiffness parameter, 110
Elastic stored energy, 234
Elastic strains and strain-increments. See Strain and strain-increments
Elastic swelling or swelling, 110
Elastic wall, 104
Elastic work, 226–7
Elasto-plastic behaviour, 125, 226, 253
Elasto-plastic physical phenomena, 120
Pseudo-elastic pre-yield behaviour, 106
Elasto-plastic model (or framework), 87, 105, 108, 112, 116, 120, 203, 253
Extended elasto-plastic critical state framework for unsaturated soils, 112
Electrical conductivity sensors, 34–5, 48–9
Delmhorst gypsum block, 49
Equilibration time, 35
Gypsum blocks, 48–9
Soilmoisture Equipment Corporation gypsum block, 49
Energy. See also Internal energy and Potentials
  Capillary component of free energy, 10
  Dissipation, 218, 224, 226–7, 229, 234–6
  Dissipated work, 226
  Elastic energy, 227–9
  Energy barrier, 140–41, 208
  Free energy, 141, 218, 224, 226–7, 253
  Free energy of soil–gas interface, 24
  Free energy of soil–mercury interface, 24
  Free energy of soil water, 10, 14
  Frozen elastic energy, 226
  Kinetic energy, 132, 135
  Negative energy dispersion, 230–2, 240, 249
  Potential energy, 137, 139, 144
  Solute component of free energy, 10
  Enthalpy, 131, 137–8, 141–2, 146–7, 149, 158–9, 160–2, 171
  Component of enthalpy of the contractile skin in an aggregate, 169
  Component of enthalpy of the contractile skin of a spherical water droplet, 169
  Enthalpy minimum principle, 137–8, 141, 148–9, 157–8, 160, 167, 171
  Enthalpy and Terzaghi’s effective stress, 162
  Enthalpy as a thermodynamic potential, 137–8, 141, 146, 149, 157–8, 160–61, 179
  Of adsorbed and absorbed water, 163
  Of aggregate, 161–2, 168–9
  Of air phase and interactions, 163
  Of contractile skin, 161, 163, 165–6, 168–70
  Of dissolved air, 163–4
  Of individual phases or interactions between phases, 162
  Of reservoir water in triaxial cell, 149
  Of solid phase and interactions, 162–4, 170
  Of unsaturated soil, 163
  Of water phase and interactions, 162–3
  Of water vapour, 163–4, 168
  Principle 1, 160–2
  Principle 2, 161–2, 167–8
  Role, 160
  Entropy, 130–1, 133–5, 143
  Envelope of isotropic compression, 203–4
Equilibration 59, 129
Equilibrium analysis, 19–21, 88, 154
Equilibrium thermostatics, 127
Chemical, 129, 144–5, 148
Mechanical (pressure and enthalpy), 129–30, 137–8, 141, 144–5, 148–9, 151, 155, 159, 171–2, 180, 224, 231–2
Of adsorbed double layer, 18
Of air bubbles, 15–17, 19
Of contractile skin, 14
Of dissolved air, 17, 164
Of pressures, 3–4, 33
Of soil water system, 34
Of vapour pressure, 14, 163
On a plane for a saturated soil, 19–20, 163
On a plane for an unsaturated soil (alternative equilibrium analysis), 172
Quasi-static, 18
Staged changes (rule of stages), 139, 141–2, 145, 176
Thermal (temperature), 129–31, 133, 145, 148, 150, 152–3
Equivalent strength parameters, 200
Essential measurements, 69–70
Etruria marl, 8
Extensive variables
Definition and meaning, 130–1, 133, 135–6, 141–4
Use of, 131, 135–6, 145–6, 156, 158, 160–61, 172, 175
Failure, 236. See also Critical state for saturated soils, Critical state for unsaturated soils and Strength
Brittle failure mechanism, 251
Extended Mohr–Coulomb failure envelope for unsaturated soils, 94
Mohr–Coulomb failure envelope for saturated soils, 94, 101
Plastic failure mechanism, 251
Post failure, 24
Filter disc
Fissured and fractured disc, 73
High air entry filter, 37–8, 43–4, 47, 52, 71–6
Saturation chamber, 73
Saturation of filter disc, 38, 71–6
Filter paper
Calibration, 50
Contact method for matric suction, 35, 49–51
Equilibration time, 35, 50–51
Equilibrium, 49–51
Method, 34, 49–51
Non-contact method for total suction, 35, 49–51
Schleicher & Schuell No. 589-WH paper, 50
Whatman No. 42 paper, 50
Fine-grained soils, 1, 5, 7–8, 11, 18, 22–3, 25, 33, 59, 93, 146, 157, 175, 180, 197, 208, 211, 213, 215, 226–7, 230, 247, 251. See also Cohesive soils
Finite-element analysis, 249
Fissures. See Discontinuities
Fitting parameter, 96
Flow rule, 107, 112, 122, 253
Fluid pressure acting through the solid phase, 19, 21, 89, 151–2, 158, 161, 164, 168, 171
Gravimetric water content. See Water content
Gravity and gravitational field, 9, 16, 19–20, 128–30. See also Potentials: Gravitational
Gypsum blocks. See Electrical conductivity sensors
Hall effect transducer, 77
Hanging column technique
Equilibration time, 35
Multiple column technique, 34–6
Vacuum control technique, 36
Hardening, 99, 107, 112, 253
Hardening law, 107
Plastic hardening, 102, 123
Suction hardening, 112
Heat. See Potentials
Henry’s law, 17, 140, 164
High-air-entry (HAE) disc. See Filter disc
Hysteresis, 19, 128, 130, 134, 139, 176–7, 179, 227
Hydraulic hysteresis (wetting–drying behaviour), 17, 112–3, 120, 124, 176–7
278  Index

Hysteresis (Continued)
  Hysteresis and collapse, 120–21, 176–7
  Instrumentation hysteresis, 46, 48–9, 80, 83

  Ideal gas laws, 164
  Illite (also Hydrous mica), 7–9
  Immiscible interactions. See Interactions
  Inclinometers, 77
  Intensive variables
    Definition and meaning, 130–1, 135–6, 142
    Use of, 131, 135–6
  Interactions
    Aggregate interactions, 175, 202, 205
    Immiscible, 142, 161, 163
    Miscible, 142, 161, 163
    Phase interactions, 1, 3, 9, 14, 33, 142–5, 149, 151, 157–8, 161–3, 167, 171, 173, 178, 228
    Soil particle interactions, 9, 18, 20, 163, 165–6, 171, 173, 175, 210, 225
  Inter-aggregate characteristics
    Bonding, 230, 247
    Contacts, 30, 32, 120, 176
    Intra-aggregate void spaces. See Voids
    Stresses, 174
    Structure, 194
    Suction, 249
  Inter-aggregate voids. See Voids
  Inter- and intra-aggregate contacts, 30, 32, 120, 176
  Intercept Ω, 184, 188–9, 192, 195, 220
  Significance of, 194–5
  Interlocking, 103, 226
  Internal energy, 131–5, 137–8, 144, 146, 148, 150–55, 158, 161, 163, 226
  Of reservoir water in triaxial cell, 148–9, 155
  Of soil specimen, 148–9, 155
  Inter-particle forces and stresses, 165, 168–9, 176
  Intra-aggregate characteristics
    Intra-aggregate void spaces. See Voids
    Intra-aggregate voids ratio, 32
    Stresses, 174
    Structure, 194
  Intra-aggregate voids. See Voids
  Jurong soil, 113, 115, 189, 191–4, 197, 209–10
  Kaolin-flint, 97
  Kelvin equation, 15
    $K_o$
    Compression, 105
    Consolidation test, 97
    Loading, 97
    $K_o$ line, 106, 112, 123
  Kinetics, 141
  Kiunyu gravel, 113, 115, 186, 188, 191–4, 197, 209–10
  Kronecker delta, 88
  Laplace equation, 15
  Lateritic gravel. See Kiunyu gravel
  Legendre transformations, 137
  Liquid limit. See Atterberg limits
  London clay, 3, 7–8, 12, 23, 26, 169, 178
  Macro-mechanical behaviour, 9, 105, 123, 125–130, 132, 146, 225, 235
  Mass, 10, 128, 130, 133, 135, 139, 142–4, 150, 161–2
    Constant water mass, 37, 113, 135, 186, 189–90, 198–9, 205, 245, 249, 253
    Mass change, 9, 14, 89, 143–5, 149, 161–2, 229, 252
    Molecular mass of water vapour, 10
    Of air, 165
    Of solids, 6, 14, 18, 92, 165
    Of water, 6, 10, 165
    Soil mass, 1, 6, 14, 131, 143, 171, 199, 210, 215, 217–9
    Total, 6
  Meta-stability. See Equilibrium
  Material preparation, 59
  Material selection, 57–8, 85
  Matric suction, 21, 87–9, 94–6, 144, 174, 179, 189
    Control, 52–3, 65, 76
    Definition, 10–2, 14–5
    Empirical matric suction parameter, 89
    Measurement, 34–8, 43, 46–7, 49–52
    Modified suction component, 121
Partial pressures. See Dalton’s divisional law and Interactions

Particle size distribution, 2

Peltier effect. See Psychrometers

Phase compressibilities, 1, 17, 36, 70, 76, 83, 136, 151–2, 162, 164, 214, 228–9, 253

Plastic behaviour, 107, 211, 226

Hyperbolic plastic potential, 112

Plastic deformation, 105, 176, 235–6

Plasticity theory, 130

Plastic potential, 99, 107, 111–12, 124, 253

Plastic strains and plastic strain–increments. See Strain and strain-increments

Plasticity index. See Atterberg limits

Plastic limit. See Atterberg limits

Polyethylene glycol (PEG), 45–6, 53–4, 68

Pore air pressure. See Air pressure

Pore size distribution. See Soil structure:

Bi-modal structure and pore size distribution

Pore spaces. See Voids

Pore water pressure, 36–8, 44, 52–3, 64–6, 69–71, 88, 94, 97, 151, 162, 164, 171–2. See also Negative pore water pressure and Suction

Porosity, 4, 5, 25, 121, 166

Dual-porosity model, 25

Term for air phase, 4, 166

Term for solid phase, 4, 166

Term for water phase, 4, 166

Potentials

Chemical, 89, 130, 133, 135, 137–8, 140, 144–5, 149, 156

Electrical, 129

Enthalpy, 137–8, 141, 146–7, 149, 157–8, 160, 179

Gibbs, 137–8, 149

Gravitational, 132, 144–5, 152–3

Heat, 135, 137, 140, 149
Potentials (Continued)
Helmholtz, 137–8, 149
Hyperbolic plastic potential. See Plastic behaviour
Internal energy, 135, 137, 146–7, 149
Magnetic, 129
Mechanical, 135, 137, 139–40, 161, 175
Minimisation and minimum principles, 137–41, 145–9, 151, 157–60, 168, 170–71, 176, 178
Plastic potential. See Plastic behaviour
Thermodynamic, 128, 131, 135, 137–47, 149, 151, 155–61, 167, 171, 175–6, 178–9, 208
Preferential shearing, 182, 187, 194, 197, 210–11
Pressure plate, 34–8, 50
  Equilibration time, 35
  Equilibrium, 36–8
Processes
  Irreversible processes, 130, 134–5, 176–8
  Reversible processes, 128, 130, 133–5, 138, 145, 150, 177, 224
Psychrometers, 34–5, 52, 74
  Calibration, 40–2
  Ceramic cup–type psychrometer, 40
  Chilled mirror psychrometer, 34–5, 43, 52
  Correction factor, 40–1
  Double-junction psychrometer, 40
  Equilibration time, 35, 40, 43
  Equilibrium, 38, 43
  Peltier effect, 39, 43
  Peltier thermocouple psychrometer, 39
  Seebeck effect, 39
  Single junction thermocouple, 40
  Thermocouple psychrometers, 35, 38–43, 55–6, 74, 186, 245
  Transistor (or thermistor) psychrometer, 35, 42
  Water potential or total suction in psychrometer, 41
Radial strain. See Strain and strain-increments
Radius and radius of curvature
  Of air–water meniscus, 10–11
  Of contractile skin on two perpendicular planes, 14
  Of spherical air bubble, 16, 19, 165
  Radius of spherical water droplet, 168, 170
Rayleigh–Plesset equation, 15
Relative humidity, 10, 38–40, 42–3, 54–5
Residual soil, 3, 113. See also Jurong soil
Sample, 59–62, 116
  Definition, 57
  Sampling, 57–9, 63
  Saturation chamber, 73
  Saturation pressure of pore water over a flat surface of pure water at the same temperature, 10, 38
Scanning electron microscope (SEM), 22–3, 25, 27
  Environmental scanning electron microscope (ESEM), 23
Seebeck effect. See Psychrometers
  Semi-permeable membrane, 45–6, 53–4
  Sessile drop technique, 24
  Shape factor for the contractile skin of an aggregate, 169
Shear strain. See Strain and strain-increments
  Shear stress, 66, 88, 93–5, 197
  Shear box, 52, 58, 60, 64, 66, 69–70
  Osmotic control of suction in the shear box, 53
Shrinkage, 3, 12, 19, 24, 65, 71, 110, 112, 178
  Shrinkage limit, 14
  Simple shear, 64, 67
  Singularities in behaviour, 222, 239, 241, 247
Smectite, 7, 18. See also Bentonite and Montmorillonite
Softening, 99, 107, 249, 253
  Plastic softening, 103, 234
  Softening law, 107
Soil fabric. See Soil structure
  Soil structure, 22–3, 25, 33, 59, 93, 100, 118, 129, 141, 178, 194, 197–9, 204, 208, 237. See also Aggregates, Discontinuities and Voids
  Aggregated structure, 1, 25, 31, 61, 114, 157–9, 162, 165, 167–8, 175–6, 178, 181, 186, 194, 199, 202, 208, 211, 221, 226, 230
  Bi-modal structure and pore size distribution, 23, 25–33, 157, 164, 173–5, 180
Dispersed soil structure, 18, 22, 25, 114, 118, 176, 178, 181, 202, 208
Macro-structure, 25, 32
Micro-structure, 25
Suction-induced soil structure, 3
Soil water characteristic curve, 12, 96
Specific air volume, 92
Definition, 5
Specific gravity of the soil particles. See Density of soil particles
Specific surface (surface area of particles), 18
Specific volume, 5, 12, 29–30, 32, 65–6, 92, 100, 102, 105, 114, 116–17, 119, 123, 152, 166, 174, 177, 180, 200, 203, 215, 239, 245
Definition, 5
Specific water volume, 5, 12, 29–30, 32, 65–6, 92, 115–16, 119, 152, 166, 174, 180, 215, 239, 245
Definition, 5
Specimen
Definition, 9, 57
Size and dimensions, 9, 22, 28, 58–60, 63, 69, 92, 232
Squeezing technique (pore fluid squeezer), 35, 51–2
Stiffness parameters, 109–10
Axial strain and axial strain-increments, 32, 59, 77, 92, 213, 224, 229–30, 252
Axial strain and strain-increments between aggregates (air voids), 217–8, 251
Axial strain and strain-increments of aggregates, 215, 230, 240, 251
Compressive straining, 90–1, 228–9
Continuity relationships between strain-increments, 213
Cumulative strain-increments, 234, 237, 239–40, 243, 247, 249, 251
Degradation strain and strain-increments, 214, 221, 228–9
Deviator strain and deviator strain-increments, 92, 217–9, 223, 229, 231, 237–8, 252
Deviator strain and strain-increments between aggregates (air voids), 217, 221–2, 251
Deviator strain and strain-increments of aggregates, 217, 221–2, 225, 251
Displacement straining, 228–9, 252
Distortional straining, 225, 227–9, 252
Elastic strain and strain-increments, 99, 103–4, 120, 218–9, 224, 226–8. See also Elastic behaviour
Frictional dissipative strains, 227, 253
Free energy strain, 227, 253
Measurement of strain, 46, 59, 76–7, 86
Plastic strain and strain-increments, 99, 103, 107, 110–2, 120, 123–4, 218, 224, 226–7, 237, 253
Principal strain and strain-increments, 90
Principal strain and strain-increment directions, 90, 219
Radial strain and compression, 77
Radial strain and radial strain-increments, 92, 213, 224, 230, 232
Radial strain and strain-increments between aggregates (air voids), 217–8, 251
Radial strain and strain-increments of aggregates, 215, 251
Rotation straining, 228–9, 252
Shear strain and shear strain-increments, 90, 93, 100, 103–4, 120, 223, 225, 228–9
Strain localisation, 23, 77, 228
Volumetric strain and strain-increments, 91–2, 103–5, 214–5, 221, 223, 225, 231, 233, 236, 252
Volumetric strain and strain-increments between aggregates (air voids), 215, 217
Volumetric strain and strain-increments of aggregates, 215
Strain controlled tests, 71
No lateral (radial) strain, 70
Rate of strain, 69
Strength. See also Critical state for saturated soil, Critical state for unsaturated soil and Failure
Maximum strength, 93
Peak strength, 93, 103, 180, 190, 210, 226
Stress path, 69, 71, 89, 110, 181. See also Triaxial tests
Stress ratio parameters
Mobilised stress ratio parameter for saturated soil \( \eta_1 \), 102, 216, 220
Mobilised stress ratio parameters for unsaturated soil \( \eta_1 \) and \( \eta_2 \), 217–18, 220, 229, 251, 253
Stress ratio parameter for saturated soils \( M \), 101, 103, 114, 216, 251
Total and suction stress ratio parameters for unsaturated soils \( M_a \) and \( M_b \), 113, 115, 184, 191, 193–4, 200, 210, 217, 220
Suction. See Matric suction, Negative pore water pressure, Osmotic suction, Total suction and Tensile suction force
Suction probe. See Tensiometers
Surface area of particles. See Specific surface
Surface tension, 1, 14, 89. See also Air–water interface and Contractile skin
Forces, 17–8, 120
Of air–water interface (contractile skin), 10, 157, 161, 165, 170
Of mercury, 24
Swelling, 29–30, 32, 64–5, 71, 88, 97, 103, 110, 120, 176
Crystalline swelling. See Crystalline swelling
Swelling clay, 18–19, 23, 165
Tempe pressure cell, 38
Tensile suction force, 8
Tensiometers, 4, 35, 43
Double tubing tensiometer, 45
Electronic pressure transducer tensiometer, 44
Equilibration time, 35
Equilibrium, 44–5
Jet fill tensiometer, 47
Imperial College tensiometer, 46–7
Mercury manometer type tensiometer, 44
MIT tensiometer, 47
NTU mini suction probe, 47
Osmotic tensiometer, 45
Suction probe (or high-capacity tensiometer), 43, 46
Trento high-capacity tensiometer, 47
Vacuum gauge tensiometer with a ‘jet-fill’ reservoir, 44
WF-DU tensiometer, 47
Terzaghi’s effective stress, 19–20, 22, 94, 172, 174, 176, 225
Effective stress tensor, 88
Mean effective stress, 22, 100, 162, 165, 169–72, 225
Testing times, 58–9, 73, 79, 86
Thermal conductivity sensors, 34–5
Equilibration time, 35
Equilibrium, 48
UOS (University of Saskatchewan) sensor, 48
Thermodynamics. See also Potentials, Thermodynamic laws, Thermodynamic pairings and Thermodynamic walls
Conjugate thermodynamic variables, 4, 89–90, 92, 125, 127, 135–6, 142–6, 154, 174–6, 179, 181, 183, 194
Equilibrium thermodynamics, 160
Equilibrium thermostatics, 127
Infinitesimal changes (steps), 128, 130, 132–4, 136, 145–6, 148–52, 154, 224, 232
Path dependency, 131–2
Principles, 90, 128, 143, 146, 171, 177, 213, 215
Potential. See Potentials
Systems, 134–5, 137
Thermodynamic laws, 130–1, 135, 155
First Law, 131, 142–3, 147, 155
Second Law, 130, 133
Third Law, 135
Zeroth Law, 131, 143
Thermodynamic pairings, 135, 142–5
Chemical potential–particle number pairing, 144
Pressure-volume pairing, 136, 143
Temperature-entropy pairing, 136, 143
Thermodynamic walls, 128–9, 143–4
Adiabatic, 129
Isolating, 129
Index 283

Open, 129
Rigid, 128
Rigid adiabatic, 148, 150
Tomography, 24
Electrical impedance tomography, 23–4
Neutron tomography, 23–4
X-ray computed tomography, 23–4, 228, 236
Total stresses internal to a soil specimen, 231
Total suction
Control, 53–4, 76
Definition, 10, 12, 14
Measurement, 34, 38–43, 49–52, 55
Time-domain reflectometry, 23
Transition between unsaturated and saturated conditions, 96, 108–9, 114, 121, 139, 181, 184, 199–200, 208, 217, 221
Assumptions, 147–9, 224
Constant suction shearing tests on 1-dimensionally prepared specimens (1d-cs), 181, 185–6, 192, 198–9, 205–6
Constant suction shearing tests on truly isotropically prepared specimens (iso-cs), 186, 192, 198–9, 205–6
Constant water mass shearing tests on specimens initially one-dimensionally compressed in layers (1d-cwm), 186, 189–90, 198–9, 205–6
Constant water mass shearing tests on truly isotropically prepared specimens (iso-cwm), 186, 198–9, 205–6
Double cell, 79
Double walled-triaxial cell, 81
Drained and undrained 'effective' stress testing, 147, 151–2, 155, 171, 229
Hollow cylinder triaxial test, 64
Idealised, 148, 152
Set-up, 52–3, 55, 73, 76, 79, 129, 138
Stress path testing, 57, 64, 69, 71, 81–2, 85–6
Techniques, 64, 71
Triaxial cell, 9, 16, 47, 52–3, 56, 62, 64, 69–70, 76–8, 90, 92, 127, 129, 134, 141, 143, 156, 179, 230, 232–3, 236, 238, 245
True triaxial apparatus, 64, 69
Twin cell, 81, 86
Undrained ‘total’ stress testing, 150, 153, 228, 230
Trois-Rivières silt, 192, 194, 197, 209–10
Truly isotropically prepared specimens, 62–3, 123, 185–6, 198–9, 204, 253
Universal gas constant, 10
Upper Lias clay (and Lias clay), 3, 8
Vapour equilibrium technique of suction control, 34–5, 53–5, 65, 70, 76
Equilibration time, 35, 55
Equilibrium, 54–5
Variables of state, 130, 135–8, 144, 149.
See also Extensive variables and Intensive variables
Virtual changes, 134, 138–9, 146, 149, 151, 171
Voids
Air voids, 3–6, 142, 167, 170, 173–5
Air voids ratio, 5
Inter-aggregate voids (pores), 5, 23, 25, 27–8, 30–33, 120, 157, 162, 175, 178, 187, 198, 205, 234, 239, 241, 243, 253
Intra-aggregate voids (pores), 8, 23, 25, 27–9, 32, 157–8, 175–6, 178
Intra-aggregate water, 167
Macro-voids ratio, 31
Voids ratio, 4, 32, 61, 92, 97, 100, 118
Water voids, 215, 235, 239, 241
Voids ratio. See Voids
Volume, 9–10, 130, 133, 135, 142–4, 161, 166. See also Aggregates, Specific air volume, Specific volume and Specific water volume
Change characteristics (behaviour), 30, 65, 87, 89, 96–7, 101–2, 108–9, 118, 124, 180–81, 204, 221
Change measurement, 34, 64, 66, 73, 76–9, 81–5
Volume (Continued)
- Of adsorbed and crystalline water, 166
- Of aggregates, 166, 170, 202, 208, 215
- Of air, 4–5, 9, 17, 131, 151, 163–5, 174, 219, 224
- Of dissolved air, 17, 164, 241, 247, 249, 253
- Of free air, 17, 140
- Of mercury, 27, 31
- Of phases, 3–4, 6, 89, 111–12, 143, 176, 180, 203, 210, 214
- Of reservoir (water in triaxial cell), 149, 153
- Of specimen, 149, 151, 154–5
- Of voids (pores), 4, 27, 202, 211
- Of water vapour, 164
  - Relationships, 3
  - Total, 4, 6, 17, 92, 131, 136, 161, 163–4, 194, 215
Volumetric strain. See Strain and strain increments
Volumetric water content, 6, 12, 96 (See also Water content)
  - Normalised volumetric water content, 12, 96
  - Residual volumetric water content, 12, 96
  - Saturated volumetric water content, 12, 96
Water content, 3, 6–7, 12, 19, 22, 30, 32, 48, 50–1, 59, 67, 69, 76, 95, 97, 166, 173, 175, 177–8, 186, 233, 239, 245. See also Volumetric water content
Compaction water content, 26–9, 32, 116, 118, 181, 198
Equilibrium water content, 36–7, 50
Gravimetric water content, 6, 12, 18, 97
Optimum water content, 6, 59, 61
Relationships, 6, 35, 47, 97
Water content index with respect to $s$, 97
Water content index with respect to $\tilde{\sigma}$, 97
Water retention behaviour, 47
Water voids. See Voids
Wavy surface, 20
Wetting and drying, 17, 49, 71, 97, 165, 170, 176, 178
Cycles, 120–1, 125, 176
Paths, 112
Deviatoric work input, 214–5, 217
Dissipated plastic work, 226–7
Elastic work, 226–7
Elastic work frozen as applied plastic work, 227
Mechanical work, 128, 143, 226
Plastic work, 226–7
Stored plastic work, 226
Virtual work, 171. See also Virtual changes
Volumetric work input, 214
Work conjugate variables. See Conjugate variables
Work done in combining phases, 161, 168
Work equation and work input equation, 147, 153–6, 213–4, 219, 224, 251
Work input, 90, 92, 127, 130, 143, 147, 155–6, 174, 213–9, 221, 223, 225–6, 229, 231–2, 234–5, 252
Work input analysis, 90, 121, 127, 146, 224, 228, 252
X-ray
  - Synchrotron radiation system, 23
  - Micro-focus X-ray systems, 23
  - X-ray computed tomography. See Tomography
  - Elliptical yield surface (locus), 105, 110, 121
  - Load-collapse yield locus ($LC$), 110, 112
  - Logarithmic yield surface (locus), 105
  - Rotation of yield locus, 106, 123
  - Suction decrease yield locus (SD), 121–2
  - Suction increase yield locus (SI), 110, 112, 121–3
  - Yield surface (locus), 99, 104–7, 110–11, 116, 124, 211, 226