



Chapter 1

Introduction

Section 1. Overview	1
Section 2. Unit System	2
Section 3. File System	3
Section 4. Notation System	4
Section 5. Sign Specification	6



Chapter 2

Node/ DOF/ Coordinate System

Section 1. Node and DOF	7
Section 2. Coordinate System	8
Section 3. Finite Rotation Simulation	10



Chapter 3

Elements

Section 1. Overview	15
<hr/>	
Section 2. Finite Element Formulation	17
<hr/>	
Section 3. Shape Function	19
3.1 1 Dimensional shape	19
3.2 2 Dimensional shape	19
3.3 3 Dimensional shape	21
3.3 Mapping Function for Infintie Element	25
<hr/>	
Section 4. Porous medium consideration	26
<hr/>	
Section 5. Supplement for Locking Phenomena	30
5.1 Mixed-hybrid formulation	30
5.2 ANS (Assumed Natural Strain)	32
5.3 EAS (Enhanced Assumed Strain)	33
5.4 Reduced integration	34
5.5 Reduced Integration stabilization	34
5.6 Non-conforming Element	35
<hr/>	
Section 6. Continuum Elements	37
6.1 Solid Elements	37
6.2 Plane Strain Elements	43
6.3 Axisymmetric Solid Elements	48
<hr/>	
Section 7. Structural Elements	52
7.1 Truss Element	52
7.2 Embedded Truss Element	54
7.3 Beam Element	56
7.4 Embedded Beam Element	63
7.5 Plane Stress Element	63
7.6 Shell Element	66



Chapter 3

Elements

Section 8. Special Purpose Elements	74
8.1 Interface Element	74
8.2 Shell Interface Element	77
8.3 Pile/Pile Tip Elements	79
8.4 Geogrid Element	81
8.5 Gauging Shell Element	82
8.6 Point Spring/Damper Element	84
8.7 Matrix Spring Element	85
8.8 Elastic Link Element	86
8.9 Rigid Link/Interpolation Element	87
8.10 Free Field Element	89
8.11 Inelastic Element	92
8.12 Infinite Element	94
Section 9. Geometric Stiffness	97
9.1 Calculation for General Elements	97
9.2 Calculation for Rigid Link	98
Section 10. Seepage Element	100
10.1 Governing Equation	100
10.2 Finite Element Equation	101
10.3 Time Integration	101
10.4 Element Matrix	101
10.5 Element Analysis Results	102
Section 11. Consolidation Element	103
11.1 Pore Pressure DOF	103
11.2 Time Integration	104
11.3 Nonlinear Increment Solution	105
11.4 Element Analysis Results	106



Chapter 4

Materials

Section 1. Elastic Material Properties	107
1.1 Isotropic Materials	107
1.2 2D Orthotropic Materials	109
1.3 Transversely Isotropic Materials	110
1.4 Elastic Material of Interface Elements	115
1.5 Nonlinear Behavior of Truss/Embedded Truss	116
1.6 Nonlinear Behavior of Elastic Link	117
1.7 Jardine	117
1.8 D-min	121
1.9 Hyperbolic Model (Duncan-Chang)	123
Section 2. Plastic Material Properties	128
2.1 Failure Criterion and Invariance	129
2.2 Formulation of Plastic Behavior	132
2.3 Von-Mises	138
2.4 Tresca	142
2.5 Mohr-Coulomb	144
2.6 Drucker-Prager	148
2.7 Strain Softening	150
2.8 Modified Cam-Clay	152
2.9 Jointed Rock	158
2.10 Modified Mohr-Coulomb	160
2.11 Hoek-Brown	163
2.12 Coulmb Friction	165
2.13 Janssen	166
2.14 Rankine/Inverse Rankine	167
2.15 Modified UBCSAND	168
2.16 Sekiguchi-Ohta (Inviscid)	173
2.17 Generalized Hoek-Brown	176
2.18 Soft Soil	177
2.19 Hardening Soil with small strain stiffness	179
2.20 Generalized SCLAY1S	184
2.21 CWFS (Cohesion Weakening and Frictional Strengthening)	190
2.22 Geogrid	191



Chapter 4

Materials

Section 3. Drained / Undrained Materials	193
3.1 Isotropic Materials	193
3.2 Undrained Constitutive Equation	193
3.3 Undrained Material Type	195
Section 4. Seepage Material Properties	197
4.1 Constitutive Equation	197
4.2 Permeability Coefficient	197
4.3 Volumetric Water Content	199
4.4 Ductile Function	200
Section 5. Viscous Material Properties	201
5.1 Age Independent Visco-elastic Material	201
5.2 Age Dependent Viso-elastic Material	205
5.3 Soft Soil Creep	207
5.4 Sekiguchi-Ohta (Viscid)	210
Section 6. Hysteresis Material Properties	213
6.1 Normal Bilinear model	214
6.2 Kinematic model	215
6.3 Origin-Oriented model	217
6.4 Peak-Oriented model	218
6.5 Clough model	219
6.6 Degrading model	220
6.7 Takeda model	221
6.8 Modified Takeda model	224
6.9 Modified Ramberg-Osgood model	227
6.10 Modified Hardin-Drnevich model	229



Chapter 5

Algorithm

Section 1. Simultaneous Equation Solver	231
Section 2. Eigenvalue Extraction	234
Section 3. Effective Mass and Mode Superposition	237
3.1 Effective Mass	237
3.2 Mode Superposition	238
Section 4. Dynamic Response	241
4.1 Time Integration	241
4.2 Frequency Response	244
4.3 Response Spectrum	245
Section 5. Nonlinear Finite Element Solution	250
Section 6. Strain/Stress Measurement Considering Large Deformation	258
Section 7. Nonlinear Dynamic Response	262
7.1 Implicit Time Integration	262
Section 8. Contact Condition	265
Section 9. Slope Stability Solution	271
9.1 Strength Reduction Method	272
9.2 Stress Analysis Method	276
Section 10. Equivalent Linear Solution	279
10.1 Free Field Analysis Method	279
10.2 2D Equivalent Linear Analysis	282



Chapter 6

Load

Constraint

Section 1. Load	287
1.1 Structural Load	287
1.2 Static/Dynamic Load Definition	290
1.3 Construction Stage Analysis Load	292
1.4 Nonlinearity of Loads	293
Section 2. Boundary and Constraint Conditions	295
2.1 Single Node Constraint	295
2.2 Multiple Node Constraint	296
2.3 Automatic Single-point Constraint	297
2.4 Constraint Force Calculation	297
2.5 Singularity Error	298
2.6 Seepage Boundary Condition	299
2.7 Transfer Boundary Condition	300
Section 3. Pore Pressure / Initial Condition	301
3.1 Pore Pressure Definition	301
3.2 Initial Condition	302
3.3 Ground Stress Initialization	304