

Contents

List of figures	xi
List of tables	xxi
1 Site investigation and soil conditions	1
1.1 Origin of rocks and soils	1
1.2 Soil strata types	5
1.3 Site investigation	7
1.4 Origin of a project	8
1.5 Pile foundations versus shallow foundations	14
1.6 Subsurface investigation phase	16
1.7 Geotechnical field tests	20
1.8 SPT (N) and friction angle	21
1.9 Field tests	21
1.10 Pressure meter testing	25
References	30
2 Geophysical methods	31
2.1 Ground-penetrating radar methods	31
2.2 Seismic method	33
3 Groundwater	37
3.1 Introduction	37
3.2 Vertical distribution of groundwater	37
3.3 Aquifers, aquicludes, aquifuges, and aquitards	39
References	44
4 Foundation types	45
4.1 Shallow foundations	45
4.2 Mat foundations	45
4.3 Pile foundations	45
4.4 Caissons	45
4.5 Foundation selection criteria	45
5 Pile types	49
5.1 Displacement piles	49
5.2 Nondisplacement piles	49
5.3 Timber piles	49

5.4	Steel 'H' piles	54
5.5	Pipe piles	55
5.6	Precast concrete piles	58
5.7	Augercast piles (continuous flight auger piles)	60
5.8	Frankie piles	65
5.9	Delta piles	66
5.10	Vibrex piles (casing removal type)	66
5.11	Compressed base type	66
5.12	Precast piles with grouted base	66
5.13	Mandrel driven piles	68
5.14	Composite piles	68
5.15	Fiber-reinforced plastic piles	70
6	Selection of piles	73
6.1	H-sections	74
6.2	Concrete piles	75
6.3	Augercast piles	76
6.4	Open- and closed-end pipe piles	77
6.5	Concrete piles	77
6.6	Augercast piles	77
6.7	H-piles	78
7	Static and dynamic analysis	81
7.1	Pile design in sandy soils (static analysis)	81
7.2	Equations for end bearing capacity in sandy soils	84
7.3	Equations for skin friction in sandy soils	85
7.4	Design examples	87
7.5	Parameters that affect end bearing capacity	94
7.6	Critical depth for end bearing capacity (sandy soils)	95
7.7	Critical depth for skin friction (sandy soils)	95
	References	97
8	Design of driven piles	99
8.1	Pile design in sandy soils (dynamic analysis)	99
8.2	Water jetting	100
8.3	Driving stresses	101
8.4	Pile design in clayey soils	102
8.5	Structural design of piles	107
8.6	Recommended guidelines for pile design	115
8.7	Uplift forces	116
8.8	Pile design in expansive soil	118
8.9	Open-ended pipe pile design: semiempirical approach	120
8.10	Case study 1: friction piles	123
8.11	Case study 2: H-sections in retaining walls	126
8.12	Design of pile groups	127

8.13	Eccentric loading on a pile group	135
8.14	Double eccentricity	137
8.15	Pile groups in clay soils	139
	References	141
9	Design of bored piles	143
9.1	Augercast pile design (empirical method)	143
9.2	Design concepts	143
9.3	Augercast pile design in sandy soils	144
9.4	Failure mechanisms of augercast piles	145
9.5	Case study: comparison between bored piles and driven piles	146
9.6	Design of pin piles: semiempirical approach	147
9.7	Bored piles in retaining walls	151
	References	154
10	Caisson design	155
10.1	Caissons in sandy soils	155
10.2	Belled caisson design	155
	Reference	157
11	Piles in rock	159
11.1	Rock joints	159
11.2	Dip angle and strike	161
11.3	Oriented rock coring	163
11.4	Oriented core data	164
11.5	Rock mass classification	165
11.6	Q system	165
11.7	Caisson design in rock	170
	References	174
12	Underpinning	175
12.1	Underpinning to stop settlement	175
12.2	Pier underpinning	175
12.3	Pier underpinning: construction procedure	176
12.4	Jack underpinning	178
12.5	Underpinning with driven piles	180
12.6	Mudjacking (underpinning concrete slabs)	181
12.7	Underpinning: case study	182
13	Pile settlement	185
13.1	Pile settlement measurement	185
13.2	Method to compute the settlement and pile compression	185
13.3	Stiffness of single piles	187
13.4	Settlement of single piles (semiempirical approach)	189
13.5	Pile settlement comparison (end bearing versus floating)	192

13.6	Critical depth for settlement	193
13.7	Pile group settlement in sandy soils	193
13.8	Long-term pile group settlement in clay soils	194
13.9	Long-term pile group settlement in clay soils Janbu method	196
13.10	Pile group settlement in sandy soils: Janbu method	198
13.11	Pile group settlement versus single pile settlement	200
13.12	Pile group design (capacity and settlement): example	201
	References	205
14	Wave equation basics	207
14.1	Assumptions	207
14.2	Representation of piles in wave equation analysis	209
14.3	Wave equation	209
14.4	Equation for tip resistance for rapid loading condition	210
14.5	Equations for skin friction for rapid loading condition	210
14.6	Example of input data for wave equation software	211
	References	212
15	Negative skin friction (downdrag)	213
15.1	Introduction	213
15.2	Bitumen-coated pile installation	213
15.3	How bitumen coating would work against downdrag	213
15.4	Original site soil profile	214
15.5	Load distribution inside piles	215
15.6	Neutral plane concept	221
16	Bitumen-coated pile design	225
16.1	Causes for negative skin friction	225
16.2	Bitumen coating	225
16.3	Bitumen behavior	225
16.4	Designing bitumen-coated piles for negative skin friction	228
16.5	Bitumen behavior during storage	230
16.6	Bitumen behavior during driving	231
16.7	Case study: bitumen-coated piles	233
	References	234
17	Laterally loaded piles	235
17.1	p - y curve method	235
17.2	Lateral loading analysis: simple procedure	238
	References	240
18	Short course on seismology	241
18.1	Faults	241
18.2	Largest earthquakes recorded	244
	Reference	245

19	Seismic analysis of piles	247
19.1	Kinematic loads	247
19.2	Inertial loads	247
19.3	Seismic pile design: inertial loads	255
19.4	Liquefaction analysis	256
19.5	Impact due to earthquakes	256
19.6	General guidelines for seismic pile design	262
	References	263
20	Batter pile design	265
20.1	Theory	265
21	Pile design software	277
21.1	Software	277
21.2	Pile design: finite element method	278
22	Pile driving methods	281
22.1	Early history of pile driving	281
22.2	Steam-operated pile hammers	281
22.3	Diesel hammers	282
22.4	Hydraulic hammers	284
22.5	Vibratory hammers	286
22.6	Pile driving procedure	290
22.7	Pile selection guide	293
22.8	General guidelines for selecting a pile hammer	293
22.9	ASTM standards	296
22.10	ACI (American Concrete Institute) standards for general concreting	297
22.11	Design stresses and driving stresses	297
22.12	Vibratory hammers: design of piles	297
22.13	Pile driving through obstructions	301
22.14	Pile heave and redriving	303
22.15	Case study	303
22.16	Soil displacement during pile driving	304
	References	305
23	Water jetting	307
23.1	Water jet types	307
23.2	Ideal water pathway	307
23.3	Water requirement	309
	Reference	310
24	Pile load testing	311
24.1	Theory	311
24.2	Pile load test procedure	311

25	Pile construction verification	315
25.1	Straightness of the pile	315
25.2	Damage to the pile	315
25.3	Plumpness of piles	315
25.4	Pile integrity testing	317
25.5	Use of existing piles	319
25.6	Environmental issues	320
25.7	Utilities	321
26	Pile identification plan	325
27	As built plans	327
27.1	Batter information	327
27.2	Use of as-built plans	327
28	Code issues (Eurocode and other building codes)	329
28.1	Eurocode	329
28.2	Design using static load tests	329
28.3	Compute characteristic axial compression load using ground tests	331
28.4	NYC building code	332
29	Economic considerations and costing	335
29.1	Pile material	335
29.2	Transportation cost	335
29.3	Pile length	335
29.4	Splicing cost	336
29.5	Equipment cost	336
29.6	Labor market	336
29.7	Cost estimate for pile driving projects	336
	Subject Index	339