

Contents

<i>Preface to the Third Edition</i>	<i>vii</i>
<i>Preface to the First Edition</i>	<i>ix</i>
1. Introduction	1
1.1 Kinds of Piles	2
1.1.1 <i>Timber/Bamboo Piles</i>	2
1.1.2 <i>Concrete Piles</i>	2
1.2 Batter Piles (Inclined Piles)	6
1.3 Test Pile	7
1.4 Working Pile	7
1.5 Trial Pile	7
2. General Considerations for Design of Piles	8
2.1 Introduction	8
2.2 Data for Pile Design	8
2.3 Various Factors for Pile Foundation Design	9
2.3.1 <i>Spacing of Piles other than Under-reamed Piles</i>	9
2.3.2 <i>Spacing of the Under-reamed Piles</i>	9
2.3.3 <i>Length of Piles</i>	10
2.3.4 <i>Length of Under-reamed Piles</i>	10
3. Design of Pile Foundations	13
3.1 Introduction	13
3.1.1 <i>Allowable Load</i>	13
3.1.2 <i>Safe Load</i>	13
3.1.3 <i>Ultimate Load Capacity</i>	13
3.1.4 <i>Working Load</i>	13
3.1.5 <i>Cut-off Level</i>	13
3.1.6 <i>Total Elastic Displacement</i>	13
3.1.7 <i>Total Displacement/Gross Displacement</i>	13
3.1.8 <i>Set</i>	13
3.1.9 <i>Net Displacement</i>	14
3.1.10 <i>Drop or Stroke</i>	14
3.1.11 <i>Factor of Safety</i>	14
3.2 Piles in Sand	14
3.3 Piles in Clay	14
3.4 Determination of Pile Capacity	15
3.4.1 <i>Pile Capacity by Static Formulae</i>	15
3.4.2 <i>Pile Capacity by Dynamic Formulae</i>	16
3.4.3 <i>Capacity of Bored Pile in Clay</i>	18
3.4.4 <i>Piles in Granular Soils (As per BIS code)</i>	20
3.4.5 <i>Capacity of Under-reamed Pile Foundation in Clays</i>	23
3.4.6 <i>Capacity of Under-reamed Pile Foundation in Sandy Soils</i>	25

3.4.7 Uplift Load Capacity of Under-reamed Pile	25
3.4.8 Other Methods to Evaluate Pile Capacity	26
3.5 Structural Design of Under-reamed Piles (After CBRI Handbook)	27
3.6 Determination of Safe Loads on Under-reamed Piles	27
3.7 Granular Pile Foundations	28
3.8 Capacity of Piles in Intermediate Geo-Material and Rock	32
3.8.1 Axial Load Carrying Capacity	32
3.8.2 Moment Carrying Capacity of Socketed Piles	34
3.9 Pile Termination Criteria as a Quality Control Tool in Rocks	34
4. Group of Piles	36
4.1 Introduction	36
4.2 Efficiency of Pile Groups	38
4.3 Settlement of Pile Groups	38
4.4 Design of Pile Cap	39
4.5 Design of Grade Beams	42
4.6 Structural Designs of Piles and Pile Groups in Various Conditions	43
4.6.1 Load Transfer Mechanism in Large Diameter Piles	43
4.7 Practical Selection of Pile Parameters	45
4.8 Batter Piles	47
4.9 Boundary Conditions for Pile Analysis	51
4.10 Sample Design of Pile Foundation for Bridge Pier	52
4.10.1 Piles in non-river bridge crossings	52
4.11 Analysis for Lateral Load Capacity of Piles	57
4.12 Structural Design of Piles for Lateral Loads	60
4.13 Sample Calculation for Proposed Elevated Road Along A Nallah in New Delhi	68
5. Pile Load Tests	78
5.1 Introduction	78
5.2 Preparation of Pile for Test (IS: 2911 Part IV)	78
5.3 Initial Test	80
5.3.1 The Safe Vertical Load on Single Pile for the Initial Test Should be Least of the Following	81
5.3.2 The Safe Vertical Load on Groups of Piles for Initial Test shall be Least of the Following	81
5.3.3 Maintained Load Method	82
5.3.4 Safe Load Through Initial Test (Pile Group)	82
5.4 Routine Test	82
5.5 Cyclic Loading Test	83
5.6 Lateral Load Test on Pile	84
5.7 Pull Out Test on Pile	86
5.8 Constant Rate of Penetration Test	86
5.8.1 Ultimate Load Capacity from Graphs	87
6. Design Examples	96
6.1 Background	96
6.2 Design Steps for Pile Design for Building	98

6.2.1 Design Steps	99
6.2.2 Design of Pile Group or Pile Layout	99
6.3 Design of Pile Cap	107
6.3.1 Isolated Pile Cap	107
6.3.2 Combined Pile Caps	110
6.4 Simplified Design of Stone Column/Granular Pile	116
6.4.1 Load Capacity of Granular Pile/Stone Column	117
6.4.2 Design of Granular Piles Under Uplift Loads	130
6.4.3 Work Done in IIT Roorkee on Granular Pile Under Uplift Loads (Kumar, 2002)	132
6.5 Scour Depth Computation in Soft Rock (Mittal, Sawant and Sahu, 2016)	138
6.6 Piles in a Group	144
6.6.1 Group Efficiency	144
6.6.2 Ultimate Capacity of Group Piles in Saturated Clay	147
7. Introduction of Spliced Piles in India	153
7.1 Introduction	153
7.2 Development of Pile Joints	154
7.3 Procedure of Casting Piles	154
7.4 Bending Test on Pre-Cast Spliced Piles	155
7.5 Sub-Soil Condition	157
7.6 Driving of Piles	158
7.7 Load Test on Piles	161
7.7.1 Compressive Load Test	161
7.7.2 Lateral Load Test	162
7.7.3 Pull Out Tests	162
7.8 Summary	163
8. Pile Construction Equipments and Construction Technology	165
8.1 Introduction	165
8.2 Tripod	165
8.3 Auger	166
8.4 Auger Boring Guide	167
8.5 Under Reamer	169
8.6 Construction Methodology of Bored Piles	170
8.6.1 Construction in Sandy Strata	171
8.6.2 Construction of Compaction Pile (i.e where Firstly Concrete is Poured, Followed by Insertion of Reinforcement Cage)	172
8.7 Pile Construction by DMC (Direct Mud Circulation) Method	174
8.8 Pile Construction by TMR (Not a Standardised Method)	175
9. Introduction of Well Foundations	176
9.1 Introduction	176
9.2 Types of Well Foundations: Classification on the Basis of Well Cross-Section	178
9.2.1 Circular	178
9.2.2 Double-D Well	178
9.2.3 Double Octagonal Well	178
9.2.4 Twin Circular Well	179

9.2.5 Rectangular Well	179
9.2.6 Wells with Multiple Dredge Holes	180
9.3 Wells and Caissons	180
9.4 Components of a Well Foundation	180
9.4.1 Bottom Plug	180
9.4.2 Top Plug	183
9.4.3 Well Cap	183
9.4.4 Steining	183
9.4.5 Well Curb or Well Kerb	184
9.4.6 Cutting Edge	184
9.5 Depth of Well Foundation	185
9.6 Well in Water	187
9.7 Use of Caissons	188
9.7.1 Assembly of Caisson on a Slipway and Launching from a Loose Earth Platform	189
9.8 Sinking of Wells: Some Problems and Solutions	190
9.9 Tilts and Shifts (IRC: 78-1983)	190
9.9.1 Causes of Tilts and Shifts	190
9.9.2 Rectification of Tilts and Shifts	191
9.10 Lateral Load Behaviour of Well Foundations	192
9.10.1 Vertical Load Capacity	194
9.10.2 Lateral Load Capacity	194
9.10.3 Uplift Capacity	195
10. Well Foundation Construction in Bouldery Bed	205
10.1 Introduction	205
10.2 Well Foundation an Overview	205
10.3 Construction of Bridge in Bouldery Bed	206
10.4 Well Foundation Construction	208
10.4.1 Dimwe Bridge	208
10.4.2 Dalai Bridge	211
10.5 Caisson Launching	214
10.5.1 Design Details	214
10.5.2 Steel Caisson Launching	215
10.5.3 Sequence of Activities	215
10.5.4 Problems	217
10.6 Pneumatic Sinking	218
10.6.1 Essential Parts and Technical Specification of Pneumatic Caisson	218
10.6.2 Hours of Work in Compresses Air	220
10.6.3 Physiological Effects of Compressed Air	220
10.6.4 Preventions and Cure for Caisson Sickness	220
10.6.5 General Precautions to Avoid Caisson Sickness	221
10.7 Tilt Rectification	222
10.7.1 Design and Layout of Rectification Scheme	223
10.8 Major Problems Encountered	225
10.9 Recommendations and Conclusions	225
10.10 Well Foundations of Solani Aqueducts (Old and New) for Upper Ganges Canal (U.G.C.) Roorkee	226
10.10.1 Introduction	226

10.11 Solani Aqueduct (Old)	227
10.12 New Solani Aqueduct	230
10.13 Concluding Remarks	234
Appendix A—The Drilling Mud (Bentonite)	237
A1 Introduction	237
A2 Properties	237
A3 Functions of Bentonite	237
A4 Specifications of Drilling Mud	237
A5 Preparation of Slurry	238
Appendix B—Concrete Grade	239
Appendix C—Foundation Pile Diagnostic System	240
C1 Introduction	240
C2 Dynamic Pile Testing	240
Appendix D—Various Soil Properties and Relationships	242
D1 Properties of Soils	242
D2 Safe Bearing Pressure of Soils (Average Values)	242
D3 Important Relationships of Various Soil Parameters	242
Appendix E—Useful Conversions	244
Appendix F—Pile Instrumentation	249
F1 Introduction	249
F2 Test Procedure for Vertical Load Test for Individual Test <i>Pile</i> or a <i>Pile Group</i>	251
F2.1 Loading Apparatus	252
F2.2 Equipment/Instruments to Monitor Movements	254
F2.3 Instruments to Monitor Load and Strain	259
F2.3.1 Load Monitoring	259
F2.3.2 Strain Monitoring	260
F2.4 Procedure to Apply Load	263
F2.4.1 Compression Pile Load Test	263
F2.4.2 Compression Testing Load Test for a Group of Piles	265
F2.4.3 Tension Pile Load Test	267
F2.4.4 Lateral Pile Load Test	268
F2.4.5 Results of Test	268
F3 Instrumentation of Steel Driven Piles	272
F3.1 Gauge Selection	273
F3.2 Strain Gauge Protection	273
F3.3 Conclusion	273
Appendix G—Quality Assurance of Deep Foundation	274
Bibliography	287
Index	289