

# Contents

About the Author	xi
Other Books by this Author	xiii
Preface	xv
Acknowledgments	xix
Notes for Students and Instructors	xxi
Notation, Abbreviations, Unit Notation, and Conversion Factors	xxv
<b>1 Composition and Particle Sizes of Soils</b>	<b>1</b>
1.1 Introduction	1
1.2 Definitions of Key Terms	1
1.3 Composition of Soils	2
1.3.1 Soil formation	2
1.3.2 Soil types	2
1.3.3 Soil minerals	3
1.3.4 Surface forces and adsorbed water	5
1.3.5 Soil fabric	6
1.4 Determination of Particle Size	7
1.4.1 Particle size of coarse-grained soils	7
1.4.2 Particle size of fine-grained soils	9
1.5 Characterization of Soils Based on Particle Size	10
1.6 Comparison of Coarse-Grained and Fine-Grained Soils for Engineering Use	19
1.7 Summary	20
Exercises	20
<b>2 Phase Relationships, Physical Soil States, and Soil Classification</b>	<b>23</b>
2.1 Introduction	23
2.2 Definitions of Key Terms	23
2.3 Phase Relationships	24

2.4	Physical States and Index Parameters of Fine-Grained Soils	36
2.5	Determination of the Liquid, Plastic, and Shrinkage Limits	40
2.5.1	Casagrande's cup method	40
2.5.2	Plastic limit test	41
2.5.3	Fall Cone Method to Determine Liquid and Plastic Limits	42
2.5.4	Shrinkage limit	43
2.6	Soil Classification Schemes	47
2.6.1	The Unified Soil Classification System (USCS)	47
2.6.2	Plasticity chart	48
2.7	Engineering Use Chart	50
2.8	Summary	53
2.8.1	Practical examples	53
	Exercises	56
3	Soils Investigation	61
3.1	Introduction	61
3.2	Definitions of Key Terms	62
3.3	Purposes of a Soils Investigation	62
3.4	Phases of a Soils Investigation	63
3.5	Soils Exploration Program	64
3.5.1	Soils exploration methods	65
3.5.1.1	Geophysical methods	65
3.5.1.2	Destructive methods	69
3.5.2	Soil identification in the field	70
3.5.3	Number and depths of boreholes	73
3.5.4	Soil sampling	74
3.5.5	Groundwater conditions	76
3.5.6	Types of in situ or field tests	77
3.5.6.1	Vane shear test (VST)	78
3.5.6.2	Standard penetration test (SPT)	79
3.5.6.3	Cone penetrometer test (CPT)	85
3.5.6.4	Pressuremeter	88
3.5.6.5	Flat plate dilatometer (DMT)	88
3.5.7	Soils laboratory tests	90
3.5.8	Types of laboratory tests	90
3.6	Soils Report	91
3.7	Summary	93
	Exercises	94
4	One- and Two-Dimensional Flows of Water Through Soils	97
4.1	Introduction	97
4.2	Definitions of Key Terms	97
4.3	One-Dimensional Flow of Water Through Saturated Soils	98
4.4	Flow of Water Through Unsaturated Soils	101
4.5	Empirical Relationship for $k_z$	101
4.6	Flow Parallel to Soil Layers	103
4.7	Flow Normal to Soil Layers	104

4.8	Equivalent Hydraulic Conductivity	104
4.9	Laboratory Determination of Hydraulic Conductivity	106
4.9.1	Constant-head test	106
4.9.2	Falling-head test	107
4.10	Two-Dimensional Flow of Water Through Soils	110
4.11	Flownet Sketching	112
4.11.1	Criteria for sketching flownets	113
4.11.2	Flownet for isotropic soils	114
4.12	Interpretation of Flownet	114
4.12.1	Flow rate	114
4.12.2	Hydraulic gradient	115
4.12.3	Critical hydraulic gradient	115
4.12.4	Porewater pressure distribution	116
4.12.5	Uplift forces	116
4.13	Summary	117
4.13.1	Practical examples	117
	Exercises	121
<b>5</b>	<b>Soil Compaction</b>	<b>125</b>
5.1	Introduction	125
5.2	Definition of Key Terms	125
5.3	Benefits of Soil Compaction	126
5.4	Theoretical Maximum Dry Unit Weight	126
5.5	Proctor Compaction Test	126
5.6	Interpretation of Proctor Test Results	129
5.7	Field Compaction	135
5.8	Compaction Quality Control	137
5.8.1	Sand cone	137
5.8.2	Balloon test	139
5.8.3	Nuclear density meter	140
5.8.4	Comparisons among the three popular compaction quality control tests	140
5.9	Summary	141
5.9.1	Practical example	141
	Exercises	143
<b>6</b>	<b>Stresses from Surface Loads and the Principle of Effective Stress</b>	<b>147</b>
6.1	Introduction	147
6.2	Definition of Key Terms	147
6.3	Vertical Stress Increase in Soils from Surface Loads	148
6.3.1	Regular shaped surface loads on a semi-infinite half-space	148
6.3.2	How to use the charts	153
6.3.3	Infinite loads	154
6.3.4	Vertical stress below arbitrarily shaped areas	155
6.4	Total and Effective Stresses	164
6.4.1	The principle of effective stress	164
6.4.2	Total and effective stresses due to geostatic stress fields	165

6.4.3	Effects of capillarity	166
6.4.4	Effects of seepage	167
6.5	Lateral Earth Pressure at Rest	175
6.6	Field Monitoring of Soil Stresses	176
6.7	Summary	177
6.7.1	Practical example	177
	Exercises	179
<b>7</b>	<b>Soil Settlement</b>	<b>185</b>
7.1	Introduction	185
7.2	Definitions of Key Terms	185
7.3	Basic Concept	186
7.4	Settlement of Free-Draining Coarse-Grained Soils	189
7.5	Settlement of Non-Free-Draining Soils	190
7.6	The One-Dimensional Consolidation Test	191
7.6.1	Drainage path	193
7.6.2	Instantaneous load	193
7.6.3	Consolidation under a constant load: primary consolidation	194
7.6.4	Effective stress changes	194
7.6.5	Effects of loading history	196
7.6.6	Effects of soil unit weight or soil density	196
7.6.7	Determination of void ratio at the end of a loading step	198
7.6.8	Determination of compression and recompression indexes	198
7.6.9	Determination of the modulus of volume change	199
7.6.10	Determination of the coefficient of consolidation	200
7.6.10.1	Root time method (square root time method)	201
7.6.10.2	Log time method	202
7.6.11	Determination of the past maximum vertical effective stress	203
7.6.11.1	Casagrande's method	203
7.6.11.2	Brazilian method	204
7.6.11.3	Strain energy method	204
7.6.12	Determination of the secondary compression index	206
7.7	Relationship between Laboratory and Field Consolidation	214
7.8	Calculation of Primary Consolidation Settlement	216
7.8.1	Effects of unloading/reloading of a soil sample taken from the field	216
7.8.2	Primary consolidation settlement of normally consolidated fine-grained soils	217
7.8.3	Primary consolidation settlement of overconsolidated fine-grained soils	217
7.8.4	Procedure to calculate primary consolidation settlement	218
7.9	Secondary Compression	219
7.10	Settlement of Thick Soil Layers	219
7.11	One-Dimensional Consolidation Theory	222
7.12	Typical Values of Consolidation Settlement Parameters and Empirical Relationships	224
7.13	Monitoring Soil Settlement	225

7.14 Summary	226
7.14.1 Practical example	226
Exercises	230
<b>8 Soil Strength</b>	<b>237</b>
8.1 Introduction	237
8.2 Definitions of Key Terms	237
8.3 Basic Concept	238
8.4 Typical Response of Soils to Shearing Forces	238
8.4.1 Effects of increasing the normal effective stress	240
8.4.2 Effects of overconsolidation ratio, relative density, and unit weight ratio	241
8.4.3 Effects of drainage of excess porewater pressure	243
8.4.4 Effects of cohesion	244
8.4.5 Effects of soil tension and saturation	245
8.4.6 Effects of cementation	246
8.5 Three Models for Interpreting the Shear Strength of Soils	247
8.5.1 Coulomb's failure criterion	248
8.5.2 Mohr–Coulomb failure criterion	249
8.5.2.1 Saturated or clean, dry uncemented soils at critical state	250
8.5.2.2 Saturated or clean, dry uncemented soils at peak state	250
8.5.2.3 Unsaturated, cemented, cohesive soils	250
8.5.3 Tresca's failure criterion	252
8.6 Factors Affecting the Shear Strength Parameters	254
8.7 Laboratory Tests to Determine Shear Strength Parameters	256
8.7.1 A simple test to determine the critical state friction angle of clean coarse-grained soils	256
8.7.2 Shear box or direct shear test	256
8.7.3 Conventional triaxial apparatus	266
8.7.4 Direct simple shear	276
8.8 Specifying Laboratory Strength Tests	277
8.9 Estimating Soil Parameters from in Situ (Field) Tests	278
8.9.1 Vane shear test (VST)	278
8.9.2 Standard penetration test (SPT)	279
8.9.3 Cone penetrometer test (CPT)	280
8.10 Some Empirical and Theoretical Relationships for Shear Strength Parameters	281
8.11 Summary	282
8.11.1 Practical examples	282
Exercises	287
Appendix A: Derivation of the One-Dimensional Consolidation Theory	291
Appendix B: Mohr's Circle for Finding Stress States	295
Appendix C: Frequently Used Tables of Soil Parameters and Correlations	296
Appendix D: Collection of Equations	307
References	319
Index	323