

CONTENTS

PREFACE	xiii
1 PROPERTIES OF SOIL	1
1.1 Soil Formation / 1	
1.2 Physical Parameters of Soils / 3	
1.2.1 Relative Density / 7	
1.3 Mechanical Properties of Soil / 8	
1.3.1 Sieve Analysis / 8	
1.3.2 Hydrometer Analysis / 10	
1.4 Soil Consistency / 11	
1.4.1 Liquid Limit / 12	
1.4.2 Plastic Limit / 12	
1.4.3 Shrinkage Limit / 12	
1.5 Plasticity Chart / 13	
1.6 Classification Systems / 14	
1.7 Compaction / 16	
2 ELASTICITY AND PLASTICITY	21
2.1 Introduction / 21	
2.2 Stress Matrix / 22	

- 2.3 Elasticity / 23
 - 2.3.1 Three-Dimensional Stress Condition / 23
 - 2.3.2 Uniaxial Stress Condition / 24
 - 2.3.3 Plane Strain Condition / 25
 - 2.3.4 Plane Stress Condition / 27
- 2.4 Plasticity / 28
- 2.5 Modified Cam Clay Model / 28
 - 2.5.1 Normal Consolidation Line and Unloading–Reloading Lines / 30
 - 2.5.2 Critical-State Line / 33
 - 2.5.3 Yield Function / 36
 - 2.5.4 Hardening and Softening Behavior / 36
 - 2.5.5 Elastic Moduli for Soil / 38
 - 2.5.6 Summary of Modified Cam Clay Model Parameters / 39
 - 2.5.7 Incremental Plastic Strains / 40
 - 2.5.8 Calculations of the Consolidated–Drained Stress–Strain Behavior of a Normally Consolidated Clay Using the Modified Cam Clay Model / 42
 - 2.5.9 Step-by-Step Calculation Procedure for a CD Triaxial Test on NC Clays / 44
 - 2.5.10 Calculations of the Consolidated–Undrained Stress–Strain Behavior of a Normally Consolidated Clay Using the Modified Cam Clay Model / 47
 - 2.5.11 Step-by-Step Calculation Procedure for a CU Triaxial Test on NC Clays / 49
 - 2.5.12 Comments on the Modified Cam Clay Model / 53
- 2.6 Stress Invariants / 53
 - 2.6.1 Decomposition of Stresses / 55
- 2.7 Strain Invariants / 57
 - 2.7.1 Decomposition of Strains / 57
- 2.8 Extended Cam Clay Model / 58
- 2.9 Modified Drucker–Prager/Cap Model / 61
 - 2.9.1 Flow Rule / 63
 - 2.9.2 Model Parameters / 64
- 2.10 Lade’s Single Hardening Model / 68
 - 2.10.1 Elastic Behavior / 68
 - 2.10.2 Failure Criterion / 68
 - 2.10.3 Plastic Potential and Flow Rule / 69
 - 2.10.4 Yield Criterion / 72

2.10.5 Predicting Soil's Behavior Using Lade's Model: CD Triaxial
Test Conditions / 82

3 STRESSES IN SOIL

90

- 3.1 Introduction / 90
- 3.2 In Situ Soil Stresses / 90
 - 3.2.1 No-Seepage Condition / 93
 - 3.2.2 Upward-Seepage Conditions / 97
 - 3.2.3 Capillary Rise / 99
- 3.3 Stress Increase in a Semi-Infinite Soil Mass Caused by External Loading / 101
 - 3.3.1 Stresses Caused by a Point Load (Boussinesq Solution) / 102
 - 3.3.2 Stresses Caused by a Line Load / 104
 - 3.3.3 Stresses Under the Center of a Uniformly Loaded Circular Area / 109
 - 3.3.4 Stresses Caused by a Strip Load ($B/L \approx 0$) / 114
 - 3.3.5 Stresses Caused by a Uniformly Loaded Rectangular Area / 116

4 CONSOLIDATION

124

- 4.1 Introduction / 124
- 4.2 One-Dimensional Consolidation Theory / 125
 - 4.2.1 Drainage Path Length / 127
 - 4.2.2 One-Dimensional Consolidation Test / 127
- 4.3 Calculation of the Ultimate Consolidation Settlement / 131
- 4.4 Finite Element Analysis of Consolidation Problems / 132
 - 4.4.1 One-Dimensional Consolidation Problems / 133
 - 4.4.2 Two-Dimensional Consolidation Problems / 147

5 SHEAR STRENGTH OF SOIL

162

- 5.1 Introduction / 162
- 5.2 Direct Shear Test / 163
- 5.3 Triaxial Compression Test / 170
 - 5.3.1 Consolidated–Drained Triaxial Test / 172
 - 5.3.2 Consolidated–Undrained Triaxial Test / 180
 - 5.3.3 Unconsolidated–Undrained Triaxial Test / 185
 - 5.3.4 Unconfined Compression Test / 186
- 5.4 Field Tests / 186
 - 5.4.1 Field Vane Shear Test / 187

- 5.4.2 Cone Penetration Test / 187
- 5.4.3 Standard Penetration Test / 187
- 5.5 Drained and Undrained Loading Conditions via FEM / 188

6 SHALLOW FOUNDATIONS

209

- 6.1 Introduction / 209
- 6.2 Modes of Failure / 209
- 6.3 Terzaghi's Bearing Capacity Equation / 211
- 6.4 Meyerhof's General Bearing Capacity Equation / 224
- 6.5 Effects of the Water Table Level on Bearing Capacity / 229

7 LATERAL EARTH PRESSURE AND RETAINING WALLS

233

- 7.1 Introduction / 233
- 7.2 At-Rest Earth Pressure / 236
- 7.3 Active Earth Pressure / 241
 - 7.3.1 Rankine Theory / 242
 - 7.3.2 Coulomb Theory / 246
- 7.4 Passive Earth Pressure / 249
 - 7.4.1 Rankine Theory / 249
 - 7.4.2 Coulomb Theory / 252
- 7.5 Retaining Wall Design / 253
 - 7.5.1 Factors of Safety / 256
 - 7.5.2 Proportioning Walls / 256
 - 7.5.3 Safety Factor for Sliding / 257
 - 7.5.4 Safety Factor for Overturning / 258
 - 7.5.5 Safety Factor for Bearing Capacity / 258
- 7.6 Geosynthetic-Reinforced Soil Retaining Walls / 271
 - 7.6.1 Internal Stability of GRS Walls / 272
 - 7.6.2 External Stability of GRS Walls / 275

8 PILES AND PILE GROUPS

286

- 8.1 Introduction / 286
- 8.2 Drained and Undrained Loading Conditions / 286
- 8.3 Estimating the Load Capacity of Piles / 291
 - 8.3.1 α -Method / 291
 - 8.3.2 β -method / 297

- 8.4 Pile Groups / 301
 - 8.4.1 α -Method / 304
 - 8.4.2 β -Method / 304
- 8.5 Settlements of Single Piles and Pile Groups / 312
- 8.6 Laterally Loaded Piles and Pile Groups / 313
 - 8.6.1 Broms' Method / 314
 - 8.6.2 Finite Element Analysis of Laterally Loaded Piles / 317

9 PERMEABILITY AND SEEPAGE

332

- 9.1 Introduction / 332
- 9.2 Bernoulli's Equation / 333
- 9.3 Darcy's Law / 337
- 9.4 Laboratory Determination of Permeability / 338
- 9.5 Permeability of Stratified Soils / 340
- 9.6 Seepage Velocity / 342
- 9.7 Stresses in Soils Due to Flow / 343
- 9.8 Seepage / 346
- 9.9 Graphical Solution: Flow Nets / 349
 - 9.9.1 Calculation of Flow / 350
 - 9.9.2 Flow Net Construction / 351
- 9.10 Flow Nets for Anisotropic Soils / 354
- 9.11 Flow Through Embankments / 355
- 9.12 Finite Element Solution / 356

REFERENCES

377

INDEX

381