Preface xv

Acknowledgments xvii

| apt | er 1. Introduction | 1. |
|------------|---|-----|
| 1.1 | | |
| 1.2 1.3 | Engineering Geology / 1.2 Geotechnical Engineering Terms / 1.2 | |
| | Symbols and Units / 1.3 | |
| 1.5 | Book Outline / 1.3 | |
| rt | 1 Introduction to Earthquakes | |
| apt | er 2. Basic Earthquake Principles | 2.3 |
| 2.1 | Plate Tectonics / 2.3 2.1.1 Types of Faults / 2.11 | |
| 2.2 | Seismograph / 2.13 | |
| | Seismic Waves / 2.14 | |
| 2.4 | Magnitude of an Earthquake / 2.16 2.4.1 Local Magnitude Scale M ₁ / 2.16 | |
| | 2.4.1 Educat Magnitude Scale $M_L = 2.10$ 2.4.2 Surface Wave Magnitude Scale $M_s = -2.18$ | |
| | 2.4.3 Moment Magnitude Scale M_w / 2.18 | |
| | 2.4.4 Comparison of Magnitude Scales / 2.19 | |
| 2.5 | 2.4.5 Summary / 2.20 Intensity of an Earthquake / 2.21 | |
| | Problems / 2.21 | |
| | | |
| apt | er 3. Common Earthquake Effects | 3. |
| 3.1 | | |
| 3.2 | | |
| | 3.2.1 Description / 3.1 3.2.2 Damage Caused by Surface Rupture / 3.2 | |
| 3.3 | Regional Subsidence / 3.8 | |
| | Liquefaction / 3.14 | |
| 3.4 | | |
| | 3.4.1 Introduction / 3.14 3.4.2 Settlement and Bearing Capacity Failures / 3.15 | |

4.1

5.3

6.1

3.5.1 Types of Earthquake-Induced Slope Movement / 3.33 3.5.2 Examples of Earthquake-Induced Slope Movement / 3.34

3.4.4 Flow Slides / 3.28 3.4.5 Lateral Spreading / 3.31

3.5 Slope Movement / 3.33

| 2.6 | 3.5.3 Seismic Evaluation of Slope Stability / 3.44 |
|-------|---|
| 3.6 | Tsunami and Seiche / 3.46 |
| Chapt | er 4. Earthquake Structural Damage |
| 4.1 | Introduction / 4.1 |
| 4.2 | Earthquake-Induced Settlement / 4.2 |
| | Torsion / 4.4 |
| 4.4 | Soft Story / 4.6 |
| | 4.4.1 Definition and Examples / 4.6 |
| | 4.4.2 Pancaking / 4.10 |
| | 4.4.3 Shear Walls / 4.15 |
| | 4.4.4 Wood-Frame Structures / 4.16 |
| 4.5 | Pounding Damage / 4.18 |
| | 4.5.1 Impact Damage from Collapse of Adjacent Structures / 4.18 |
| 16 | 4.5.2 Asymmetry / 4.19 Resonance of the Structure / 4.20 |
| 4.6 | 4.6.1 Soft Ground Effects / 4.21 |
| | 4.0.1 Soft Ground Effects 7 4.21 |
| | |
| Part | 2 Geotechnical Earthquake Engineering Analyses |
| | |
| Chapt | er 5. Site Investigation for Geotechnical Earthquake Engineering |
| 5.1 | Introduction / 5.4 |
| | 5.1.1 Scope of the Site Investigation / 5.4 |
| 5.2 | Screening Investigation / 5.6 |
| 5.3 | Quantitative Evaluation / 5.10 |
| 5.4 | Subsurface Exploration / 5.11 |
| | 5.4.1 Borings, Test Pits, and Trenches / 5.11 |
| | 5.4.2 Soil Sampling / 5.15 |
| | 5.4.3 Standard Penetration Test / 5.17 |
| | 5.4.4 Cone Penetration Test / 5.22 |
| 5.5 | Laboratory Testing / 5.25 |
| | 5.5.1 Shear Strength / 5.27 |
| | 5.5.2 Cyclic Triaxial Test / 5.31 |
| 5.6 | Peak Ground Acceleration / 5.33 |
| | 5.6.1 Introduction / 5.33 |
| | 5.6.2 Methods Used to Determine the Peak Ground Acceleration / 5.34 |
| | 5.6.3 Example of the Determination of Peak Ground Acceleration / 5.36 |
| | 5.6.4 Local Soil and Geologic Conditions / 5.41 |
| 5.7 | |
| 5.8 | Problems / 5.42 |
| Chap | ter 6. Liquefaction |
| | Introduction / 62 |
| 6.1 | |
| 6.2 | 6.2.1 Laboratory Data from Ishihara / 6.2 |
| | 6.2.1 Laboratory Data from Seed and Lee / 6.6 |

| 6.3 6.4 | | |
|------------|---|-----|
| 0.5 | 6.4.1 Introduction / 6.10 | |
| | 6.4.2 Cyclic Stress Ratio Caused by the Earthquake / 6.11 | |
| | 6.4.3 Cyclic Resistance Ratio from the Standard Penetration Test / 6.14 | |
| | 6.4.4 Factor of Safety against Liquefaction / 6.17 | |
| | 6.4.5 Example Problem / 6.18 | |
| | 6.4.6 Cyclic Resistance Ratio from the Cone Penetration Test / 6.19 | |
| | 6.4.7 Cyclic Resistance Ratio from the Shear Wave Velocity / 6.19 | |
| 6.5 | 1 1 | |
| 6.6 | 6 Problems / 6.22 | |
| Chap | oter 7. Earthquake-Induced Settlement | 7.1 |
| 7. | Introduction / 7.2 | |
| 7.3 | | |
| | 7.2.1 Introduction / 7.3 | |
| | 7.2.2 Methods of Analysis / 7.3 | |
| | 7.2.3 Limitations / 7.7 | |
| 7.3 | B Liquefaction-Induced Ground Damage / 7.8 | |
| | 7.3.1 Types of Damage / 7.8 | |
| | 7.3.2 Method of Analysis / 7.9 | |
| | 7.3.3 Example Problem / 7.11 | |
| 7.4 | • | |
| | 7.4.1 Main Factors Causing Volumetric Compression / 7.12 | |
| | 7.4.2 Simple Settlement Chart / 7.12 | |
| | 7.4.3 Method by Tokimatsu and Seed / 7.13 | |
| | 7.4.4 Example Problem / 7.17 | |
| 7 | 7.4.5 Limitations / 7.19 | |
| 7.: | , , , , | |
| 7.6 | 5 Problems / 7.21 | |
| Char | oter 8. Bearing Capacity Analyses for Earthquakes | 8.1 |
| | Tel 0. Dealing Capacity Analyses for Cartifuantes | |
| 8. | 1 Introduction / 8.2 | |
| | 8.1.1 General, Punching, and Local Shear / 8.2 | |
| | 8.1.2 Bearing Capacity Failures / 8.3 | |
| | 8.1.3 Shear Strength / 8.6 | |
| | 8.1.4 One-Third Increase in Bearing Pressure for Seismic Conditions / 8.7 | |
| 8.3 | | |
| | 8.2.1 Introduction / 8.8 | |
| | 8.2.2 Punching Shear Analysis / 8.10 | |
| | 8.2.3 Terzaghi Bearing Capacity Equation / 8.15 | |
| | 8.2.4 Deep Foundations / 8.19 | |
| | 8.2.5 Other Design Considerations / 8.21 | |
| | 8.2.6 Example Problem / 8.22 | |
| 8. | 1 | |
| | 8.3.1 Introduction / 8.27 | |
| | 8.3.2 Bearing Capacity Equation / 8.27 | |
| 0 | 8.3.3 Example Problem / 8.28 | |
| 8. | 4 Bearing Capacity Analysis for Cohesive Soil Weakened by the Earthquake / 8.30 8.4.1 Introduction / 8.30 | |
| | 8.4.1 Introduction / 8.30 8.4.2 Bearing Capacity Equation / 8.30 | |
| | 8.4.3 Example Problem / 8.32 | |
| 8. | | |
| 8. | | |
| | | |

10.1

Chapter 9. Slope Stability Analyses for Earthquakes

| 9.1 | Introduction / 9.2 |
|-----|---|
| | 9.1.1 Inertia Slope Stability Analysis / 9.5 |
| | 9.1.2 Weakening Slope Stability Analysis / 9.8 |
| | 9.1.3 Cross Section and Soil Properties / 9.9 |
| 9.2 | Inertia Slope Stability—Pseudostatic Method / 9.9 |
| | 9.2.1 Introduction / 9.9 |
| | 9.2.2 Selection of the Seismic Coefficient / 9.10 |
| | 9.2.3 Wedge Method / 9.11 |
| | 9.2.4 Method of Slices / 9.13 |
| | 9.2.5 Landslide Analysis / 9.14 |
| | 9.2.6 Other Slope Stability Considerations / 9.16 |
| | 9.2.7 Example Problem / 9.18 |
| 9.3 | |
| | 9.3.1 Introduction / 9.25 |
| | 9.3.2 Example Problem / 9.29 |
| | 9.3.3 Limitation of the Newmark Method / 9.29 |
| 9.4 | |
| | 9.4.1 Introduction / 9.32 |
| | 9.4.2 Factor of Safety against Liquefaction for Slopes / 9.34 |
| | 9.4.3 Stability Analysis for Liquefied Soil / 9.36 |
| | 9.4.4 Liquefied Shear Strength / 9.42 |
| 9.5 | Weakening Slope Stability—Liquefaction-Induced Lateral Spreading / 9.44 |
| | 9.5.1 Introduction / 9.44 |
| | 9.5.2 Empirical Methods / 9.46 |
| | 9.5.3 Summary / 9.47 |
| 9.6 | Weakening Slope Stability—Strain-Softening Soil / 9.47 |
| 9.7 | |
| | 9.7.1 Allowable Lateral Movement / 9.48 |
| | 9.7.2 Mitigation Options / 9.49 |
| 9.8 | |
| 9.9 | Problems / 9.53 |
| | |

Chapter 10. Retaining Wall Analyses for Earthquakes

10.1 Introduction / 10.2 10.1.1 Retaining Wall Analyses for Static Conditions / 10.2 10.1.2 Retaining Wall Analyses for Earthquake Conditions / 10.9 10.1.3 One-Third Increase in Soil Properties for Seismic Conditions / 10.9 10.2 Pseudostatic Method / 10.10 10.2.1 Introduction / 10.10 10.2.2 Method by Seed and Whitman / 10.12 10.2.3 Method by Mononobe and Okabe / 10.12 10.2.4 Example Problem / 10.12 10.2.5 Mechanically Stabilized Earth Retaining Walls / 10.19 10.3 Retaining Wall Analyses for Liquefied Soil / 10.23 10.3.1 Introduction / 10.23

10.3.2 Design Pressures / 10.24 10.3.3 Sheet Pile Walls / 10.25

10.3.4 Summary / 10.31

10.4 Retaining Wall Analyses for Weakened Soil / 10.31

10.5 Restrained Retaining Walls / 10.32

10.5.1 Introduction / 10.32

10.5.2 Method of Analysis / 10.32

10.5.3 Example Problem / 10.33

10.6 Temporary Retaining Walls / 10.33

| | 10.6.1 Static Design / 10.33 | |
|--------|---|------|
| | 10.6.2 Earthquake Analysis / 10.35 | |
| 10.7 | Problems / 10.35 | |
| | | |
| Chapte | er 11. Other Geotechnical Earthquake Engineering Analyses | 11.1 |
| | | |
| | Introduction / 11.1 | |
| 11.2 | Surface Rupture Zone / 11.2 | |
| | 11.2.1 Introduction / 11.2 | |
| | 11.2.2 Design Approach / 11.2 | |
| 11.2 | 11.2.3 Groundwater / 11.4 | |
| 11.5 | Pavement Design / 11.5 11.3.1 Introduction / 11.5 | |
| | | |
| | 11.3.2 Flexible Pavements / 11.5 | |
| 11.4 | 11.3.3 Earthquake Design / 11.6 Pipeline Design / 11.8 | |
| 11.4 | 11.4.1 Introduction / 11.8 | |
| | 11.4.2 Static Design / 11.10 | |
| | 11.4.3 Earthquake Design / 11.15 | |
| 11.5 | Response Spectrum / 11.15 | |
| 11.5 | 11.5.1 Introduction / 11.15 | |
| | 11.5.2 Response Spectrum per the <i>Uniform Building Code</i> / 11.16 | |
| | 11.5.3 Alternate Method / 11.20 | |
| | 11.5.4 Example Problem / 11.21 | |
| 11.6 | Foundations on Rock / 11.22 | |
| 11.0 | 11.6.1 Lightly Loaded Foundations on Rock / 11.22 | |
| | 11.6.2 Heavily Loaded Foundations on Rock / 11.23 | |
| 117 | Deep Foundations / 11.25 | |
| 11., | 11.7.1 Introduction / 11.25 | |
| | 11.7.2 Vertical Loading Conditions / 11.25 | |
| | 11.7.3 Downdrag Loads / 11.36 | |
| | 11.7.4 Eccentric Loads / 11.39 | |
| | 11.7.5 Lateral Loads / 11.42 | |
| 11.8 | Problems / 11.46 | |
| 11.0 | Trobbins 7 71.70 | |
| | | |
| | | |
| Part 3 | B Site Improvement Methods to Mitigate | |
| | Earthquake Effects | |
| | · | |
| Chapte | er 12. Grading and Other Soil Improvement Methods | 12.3 |
| | | |
| | Introduction / 12.3 | |
| 12.2 | Grading / 12.4 | |
| 12.3 | Other Site Improvement Methods / 12.5 | |
| | 12.3.1 Soil Replacement / 12.5 | |
| | 12.3.2 Water Removal / 12.5 | |
| | 12.3.3 Site Strengthening / 12.8 | |
| | 12.3.4 Grouting / 12.8 | |
| | 12.3.5 Thermal / 12.10 | |
| | 12.3.6 Summary / 12.10 | |
| 12.4 | Groundwater Control / 12.10 | |
| | 12.4.1 Introduction / 12.10 | |
| | 12.4.2 Methods of Groundwater Control / 12.12 | |
| | 12.4.3 Groundwater Control for Slopes / 12.12 | |

| Chapter 13. Foundation Alternatives to Mitigate Earthquake Effects | 13. |
|--|-----|
| 13.1 Introduction / 13.1 13.2 Shallow Foundations / 13.1 13.3 Deep Foundations / 13.2 13.3.1 Introduction / 13.2 13.3.2 Pier and Grade Beam Support / 13.5 13.3.3 Prestressed Concrete Piles / 13.17 | |
| 13.4 Foundations for Single-Family Houses / 13.32 13.4.1 Raised Wood Floor Foundation / 13.34 13.4.2 Slab-on-Grade / 13.36 13.4.3 California Northridge Earthquake / 13.38 | |
| 13.5 Problems / 13.39 | |
| Part 4 Building Codes and Summary Chapter | |
| Chapter 14. Earthquake Provisions in Building Codes | 14. |
| 14.1 Introduction / 14.3 14.1.1 Code Development / 14.3 14.1.2 Limitations of Building Codes / 14.4 | |
| 14.2 International Building Code / 14.6 14.2.1 Introduction / 14.6 | |
| 14.2.2 Soils Investigation / 14.6 14.2.3 Excavation, Grading, and Fill / 14.10 14.2.4 Presumptive Load-Bearing Values / 14.10 | |
| 14.2.5 General Regulations for Footings and Foundations / 14.14 14.2.6 Retaining Walls / 14.19 14.2.7 Site Class / 14.21 | |
| 14.2.8 Peak Ground Acceleration / 14.24 14.2.9 Report Preparation / 14.27 14.3 Problems / 14.27 | |
| | |
| Chapter 15. Summary of Geotechnical Earthquake Engineering | 15. |
| 15.1 Introduction / 15.1 15.2 Summary of Site Investigation / 15.1 | |
| 15.3 Summary of Peak Ground Acceleration / 15.5 | |
| 15.3.1 MCE _G Peak Ground Acceleration / 15.5 15.4 Summary of Engineering Analyses / 15.5 | |
| 15.4.1 Materials Weakened during the Earthquake / 15.6 | |
| 15.4.2 Materials Not Weakened by the Earthquake / 15.11 15.5 Summary of Mitigation Measures / 15.13 | |
| , | |
| Appendix A. Glossaries | Α. |
| Glossary 1 Field Testing Terminology / A.2 | |
| Glossary 2 Laboratory Testing Terminology / A.5 Glossary 3 Terminology for Engineering Analysis and Computations / A.11 | |
| Glossary 4 Compaction, Grading, and Construction Terminology / A.16 | |
| Glossary 5 Earthquake Terminology / A.21 Glossary References / A.27 | |

| Appendix B. EQSEARCH, EQFAULT, and FRISKSP Computer Programs | В. |
|---|-----|
| Appendix C. Conversion Factors | C. |
| Appendix D. Example of a Geotechnical Report Dealing with Earthquake Engineering | |
| Appendix E. Solutions to Problems | E.' |
| Appendix F. References | F.′ |