Contents

1 Introduction ........................................ 1
   1.1 Introduction ..................................... 1
   1.2 Hot Research Topics ................................. 3
   1.3 Outline of the Book ................................ 4
   References ........................................... 4

2 Recent Advances ....................................... 7
   2.1 Introduction ....................................... 7
   2.2 Waves Propagating over a Porous Seabed: Theoretical Models
       (Transient Mechanism) ............................... 7
       2.2.1 Un-coupled Models (or Drained Models) ........ 8
       2.2.2 Biot’s Consolidation Model (Quasi-Static Model) .. 10
       2.2.3 $u$–$p$ Approximation .......................... 15
       2.2.4 Dynamic Models ................................. 16
       2.2.5 Poro-Elastoplastic Models ....................... 16
   2.3 Waves Propagating over a Porous Seabed: Theoretical Model
       (Residual Mechanism) ............................... 17
   2.4 Waves Propagating over a Porous Seabed: Physical Modeling ... 18
       2.4.1 Field Measurements .............................. 18
       2.4.2 Laboratory Experiments ......................... 19
   2.5 Waves Propagating over a Porous Seabed: Wave Damping
       and Seepage Flux .................................. 21
       2.5.1 Wave Damping in a Porous Seabed ............... 21
       2.5.2 Wave-Driven Seepage Flux in Sediments ......... 22
   2.6 Wave-Induced Seabed Instability .................... 22
       2.6.1 Shear Failure .................................... 23
       2.6.2 Liquefaction ..................................... 24
   References ........................................... 27

3 Wave-Induced Soil Response in an Isotropic Seabed .......... 33
   3.1 Introduction ....................................... 33
   3.2 A Short-Crested Wave System ....................... 35
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.3</td>
<td>Boundary Value Problem</td>
<td>36</td>
</tr>
<tr>
<td>3.3.1</td>
<td>Governing Equations</td>
<td>36</td>
</tr>
<tr>
<td>3.3.2</td>
<td>Boundary Conditions</td>
<td>39</td>
</tr>
<tr>
<td>3.4</td>
<td>General Solutions</td>
<td>40</td>
</tr>
<tr>
<td>3.4.1</td>
<td>Basic Theoretical Framework</td>
<td>40</td>
</tr>
<tr>
<td>3.4.2</td>
<td>Soil Response in a Seabed of Infinite Thickness</td>
<td>42</td>
</tr>
<tr>
<td>3.4.3</td>
<td>Soil Response in a Porous Seabed of Finite Thickness</td>
<td>44</td>
</tr>
<tr>
<td>3.4.4</td>
<td>Soil Response in a Layered Seabed</td>
<td>46</td>
</tr>
<tr>
<td>3.4.5</td>
<td>Limiting Two-Dimensional Conditions</td>
<td>48</td>
</tr>
<tr>
<td>3.4.6</td>
<td>A Special Case: Fully Saturated Isotropic Seabed of Infinite Thickness</td>
<td>51</td>
</tr>
<tr>
<td>3.5</td>
<td>Verification</td>
<td>52</td>
</tr>
<tr>
<td>3.5.1</td>
<td>Comparison with Two-Dimensional Experimental Data</td>
<td>52</td>
</tr>
<tr>
<td>3.5.2</td>
<td>Comparison with Two-Dimensional Analytical Solutions</td>
<td>54</td>
</tr>
<tr>
<td>3.5.3</td>
<td>Comparison with Numerical Model [18, 40, 41]</td>
<td>58</td>
</tr>
<tr>
<td>3.6</td>
<td>Results and Discussion</td>
<td>60</td>
</tr>
<tr>
<td>3.6.1</td>
<td>Effect of Wave Characteristics</td>
<td>60</td>
</tr>
<tr>
<td>3.6.2</td>
<td>Effect of Soil Characteristics</td>
<td>62</td>
</tr>
<tr>
<td>3.6.3</td>
<td>Effect of a Combined Obliquity-Permeability Parameter</td>
<td>69</td>
</tr>
<tr>
<td>3.6.4</td>
<td>Effect of a Top Layer</td>
<td>70</td>
</tr>
<tr>
<td>3.7</td>
<td>Summary</td>
<td>72</td>
</tr>
<tr>
<td>3.8</td>
<td>List of Coefficients $B_i$ and $C_i$</td>
<td>73</td>
</tr>
<tr>
<td>References</td>
<td>76</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Wave-Induced Seabed Instability</td>
<td>79</td>
</tr>
<tr>
<td>4.1</td>
<td>Introduction</td>
<td>79</td>
</tr>
<tr>
<td>4.2</td>
<td>Shear Failure</td>
<td>80</td>
</tr>
<tr>
<td>4.2.1</td>
<td>Principal Stresses</td>
<td>80</td>
</tr>
<tr>
<td>4.2.2</td>
<td>Mohr-Coulomb’s Criterion</td>
<td>82</td>
</tr>
<tr>
<td>4.3</td>
<td>Soil Liquefaction</td>
<td>83</td>
</tr>
<tr>
<td>4.3.1</td>
<td>Excess Pore Pressure</td>
<td>83</td>
</tr>
<tr>
<td>4.3.2</td>
<td>Criteria of Liquefaction</td>
<td>84</td>
</tr>
<tr>
<td>4.3.3</td>
<td>Seepage Force</td>
<td>87</td>
</tr>
<tr>
<td>4.4</td>
<td>Wave-Induced Seabed Instability</td>
<td>90</td>
</tr>
<tr>
<td>4.4.1</td>
<td>Effect of Wave Characteristics</td>
<td>90</td>
</tr>
<tr>
<td>4.4.2</td>
<td>Effect of Soil Characteristics</td>
<td>95</td>
</tr>
<tr>
<td>4.4.3</td>
<td>Effect of Combined Obliquity-Permeability Parameter</td>
<td>98</td>
</tr>
<tr>
<td>4.4.4</td>
<td>Temporal Variation in Wave-Induced Liquefaction</td>
<td>98</td>
</tr>
<tr>
<td>4.5</td>
<td>Seabed Protection</td>
<td>99</td>
</tr>
<tr>
<td>4.5.1</td>
<td>Effects of a Top Layer</td>
<td>100</td>
</tr>
<tr>
<td>4.5.2</td>
<td>Methodology of Seabed Protection</td>
<td>103</td>
</tr>
<tr>
<td>4.6</td>
<td>Summary</td>
<td>107</td>
</tr>
<tr>
<td>References</td>
<td>107</td>
<td></td>
</tr>
</tbody>
</table>
5 Wave-Induced Seabed Response in Non-homogeneous Anisotropic Seabed

5.1 Introduction ......................................................... 109
5.2 Analytical Solution for a Seabed with Variable Permeability .......... 111
  5.2.1 Boundary Value Problem .................................. 111
  5.2.2 General Solutions .......................................... 112
  5.2.3 Results and Discussion .................................... 119
  5.2.4 Summary ..................................................... 128
5.3 Analytical Solution for a Cross-Anisotropic Seabed ..................... 128
  5.3.1 Cross-Anisotropic Soil ..................................... 128
  5.3.2 Boundary Value Problem .................................. 130
  5.3.3 General Solutions .......................................... 131
  5.3.4 Results and Discussion .................................... 139
  5.3.5 Effect of Anisotropic Constant A .......................... 149
  5.3.6 Effect of the Degree of Saturation ......................... 150
  5.3.7 Summary ..................................................... 151
5.4 Numerical Model for Seabed Response in Anisotropic Seabed with Variable Soil Characteristics ........................................ 151
  5.4.1 Boundary Value Problem .................................. 153
  5.4.2 Wave-Induced Seabed Response ............................ 154
  5.4.3 Wave-Induced Liquefaction ................................ 161
  5.4.4 Summary ..................................................... 164
5.5 Appendix: Exact Solutions of Linear Variable Coefficient Equations 164
5.6 Appendix: Finite Element Formulations ................................ 167
References ............................................................. 169

6 Dynamic Analysis for Wave-seabed Interaction .......................... 173
6.1 Introduction ......................................................... 173
6.2 Boundary Value Problem .......................................... 174
  6.2.1 Basic Ocean Wave Theory ................................ 174
  6.2.2 Governing Equations ....................................... 174
  6.2.3 Boundary Conditions ....................................... 175
6.3 General Solutions .................................................. 176
  6.3.1 Basic Framework ........................................... 176
  6.3.2 A Seabed of Finite Thickness ............................... 181
  6.3.3 A Seabed of Infinite Thickness ............................. 183
6.4 Simplified Solution ................................................ 184
  6.4.1 \( u-p \) Approximation ..................................... 184
  6.4.2 Quasi-Static Approximation ................................ 186
6.5 Numerical Results and Discussions .................................. 187
  6.5.1 Effects of Dynamic Soil Behavior ........................... 187
  6.5.2 Effects of Soil Characteristics .............................. 188
  6.5.3 Effects of Wave Characteristics ............................ 193
6.6 When Should Dynamic Soil Behavior Be Considered? ..................... 197
References ............................................................. 199
7 Wave Propagation over Coulomb-Damped Seabed

7.1 Introduction
7.2 Coulomb-Damping Poro-Elastic Seabed
7.3 Boundary Value Problem
  7.3.1 Governing Equations
  7.3.2 Boundary Condition
7.4 General Solutions
  7.4.1 Analytical Solution for a Seabed of Finite Thickness
  7.4.2 Analytical Solution for an Infinite Seabed
  7.4.3 Verification
7.5 Results and Discussions
  7.5.1 Effects of Coulomb-Damping Friction and Fluid Acceleration
  7.5.2 Response of Seabed to Ocean Waves
7.6 Summary
7.7 Appendix: List of Coefficients $a_1$–$a_6$

References

8 Random Wave-Induced Seabed Response

8.1 Introduction
8.2 Random Waves
  8.2.1 Random Wave Generation
  8.2.2 Random Wave Simulation
  8.2.3 Random Wave Validation
  8.2.4 Statistic Features of the Simulated Random Waves
  8.2.5 Representative Regular Wave
8.3 Wave-Induced Oscillatory Soil Response
  8.3.1 Boundary Value Problem
  8.3.2 Analytical Solutions
8.4 Numerical Results
  8.4.1 Comparison Between Regular and Random Wave-Induced Soil Responses
  8.4.2 Effect of Soil Parameters on Random Wave-Induced Soil Response
  8.4.3 Effect of Wave Characteristics on Random Wave-Induced Soil Response
  8.4.4 Effect of Seabed Thickness on Random Wave-Induced Soil Response
8.5 Summary

References

9 Wave-Induced Pore Pressure Accumulation in Marine Sediments

9.1 Introduction
9.2 Boundary Value Problem
9.3 Source Term
  9.3.1 Nonlinear Mechanism of Pore Pressure Generation
  9.3.2 Linear Mechanism of Pore Pressure Generation

References
9.4 Theoretical Models ........................................ 256
  9.4.1 Analytical Approximation for Linear Mechanism .... 256
  9.4.2 Numerical Scheme .................................... 258
  9.4.3 Comparisons .......................................... 258
9.5 Parametric Study ........................................... 260
9.6 A Simplified Approximation for an Infinite Seabed .... 262
  9.6.1 Scaling Analysis ...................................... 262
  9.6.2 A Simplified Approximation for Wave-Induced
        Liquefaction ........................................... 265
9.7 Summary .................................................... 266
9.8 Appendix: Mathematical Derivation of Analytical Solutions ... 267
  9.8.1 Finite Soil Model .................................... 268
  9.8.2 Shallow Soil Model .................................. 268
  9.8.3 Deep Soil Model ..................................... 268
References .................................................. 270

10 Wave-Induced Progressive Liquefaction in a Porous Seabed .... 271
  10.1 Introduction ............................................ 271
  10.2 Two-Layered Fluid System ............................... 272
    10.2.1 Two-Layered Inviscid Fluid Model ................. 273
    10.2.2 Two-Layered Viscid Fluid Model .................. 273
  10.3 Poro-Elastoplastic Soil Model .......................... 276
    10.3.1 Boundary Value Problem ............................ 276
    10.3.2 Cyclic Shear Stress in an Infinite Seabed ........ 277
    10.3.3 Cyclic Shear Stress in a Seabed of Finite Thickness ... 278
    10.3.4 Numerical Scheme and Procedure ................... 279
  10.4 Results and Discussions ................................ 280
    10.4.1 Comparison with Sassa’s Model [6] ................. 281
    10.4.2 Viscous Effect and the Influence of Shear Stress ... 283
    10.4.3 Effect of Parameters $\alpha$, $\beta$ and $R$ in the Build-Up Pattern ... 284
    10.4.4 Effect of Wave and Soil Characteristics .......... 286
    10.4.5 Pore Pressure History .............................. 287
  10.5 Summary ................................................ 288
References .................................................. 288

Index ....................................................... 289
Porous Models for Wave-seabed Interactions
Jeng, D.-S.
2013, XIV, 290 p., Hardcover
ISBN: 978-3-642-33592-1