

Contents

Preface	xi
About the Author	xiii
Contributors.....	xiv
Civil and Environmental Engineering Series	xv
1 Deepwater Foundations and Pipeline Geomechanics	1
1.1 Introduction.....	1
1.2 Integrated Geophysical Investigations.....	2
1.3 Foundation Concept Selection and Design	3
1.4 Pipeline Geomechanics	4
1.5 Foundation Analysis and Centrifuge Model Testing.....	4
1.6 Probabilistic Risk Analysis.....	6
1.7 References.....	6
2 Deepwater Integrated Geosciences Studies	7
2.1 Introduction.....	7
2.1.1 Chapter Overview.....	8
2.1.2 Technological Improvements	9
2.2 Objective of an Integrated Site Investigation.....	11
2.3 Spatial Variability and Data Uncertainty.....	12
2.4 Planning Study with 3-D Seismic Data	15
2.5 Geophysical Site Survey.....	17
2.5.1 Data Acquisition.....	17
2.5.2 Deepwater Geophysical Tools	22
2.5.3 Deepwater Geophysical Survey.....	24
2.6 Geotechnical Site Investigation	27
2.6.1 Deepwater Data Acquisition.....	27
2.7 Performing the Geotechnical Site Investigation.....	29
2.7.1 Sampling Procedures	29
2.7.2 Deepwater In Situ Testing Methods.....	37
2.7.3 Cone Penetrometer Testing	38
2.7.4 Use of CPT Data.....	43
2.7.5 In Situ Vane Shear Testing	50
2.7.6 Use of VST Data	53
2.7.7 In Situ Piezoprobe	54
2.8 Integrated Case Studies.....	55
2.8.1 Geologic Setting and Field Architectures	56
2.8.2 Mad Dog and Atlantis Geo-constraints	59
2.8.3 Refining Integrated Geologic Model	60

2.8.4	Geotechnical Investigation Objectives	64
2.8.5	Laboratory Testing Program.....	64
2.8.6	In Situ Data Interpretation.....	70
2.8.7	Interpreted Shear Strength Profile	72
2.8.8	Uncertainty in Data Interpretation.....	72
2.8.9	Final Geologic/Geotechnical Model Integration	75
2.8.10	Site Favorability Assessment.....	80
2.8.11	Foundation Site Evaluation.....	90
2.9	Objective and Benefits of Integrated Geosciences Studies.....	91
2.10	Conclusion	93
2.11	Acknowledgments	95
2.12	References.....	96
3	Deepwater Foundation Design.....	103
3.1	Background	103
3.2	Deepwater Foundation Applications	104
3.2.1	Foundations for Moorings	105
3.2.2	Foundations for Seafloor Facilities	107
3.3	Foundation Design Requirements	107
3.3.1	Analytical Procedures.....	108
3.3.2	Interpreted Soil Properties.....	109
3.3.3	Soil Strength Profile	111
3.4	Deepwater Anchors.....	113
3.5	Anchor Line	116
3.5.1	Post Tensioning of the Anchor.....	118
3.5.2	Interaction Tensioning of the Anchor	118
3.6	Pipe Piles.....	120
3.6.1	Driven Pipe Piles.....	120
3.6.2	Axial Capacity.....	121
3.6.3	Lateral Capacity.....	124
3.6.4	Jetted Piles.....	127
3.7	Drilled and Grouted Piles.....	128
3.8	Suction Caisson	129
3.8.1	Suction Caisson Design Geometry.....	129
3.8.2	Key Design Factors	130
3.8.3	Design Procedures	131
3.8.4	Installation Procedure	135
3.9	Vertical Loaded Anchors (VLA)	138
3.9.1	VLA Geometry	140
3.9.2	Key Design Factors	140
3.9.3	Installation Procedures.....	140
3.9.4	Anchor Installation Plan and Performance	141
3.10	SEPLA	142
3.11	Gravity-installed Anchors	143
3.11.1	Installation Procedures.....	145
3.11.2	Design Methods	146
3.12	Foundations for Seafloor Facilities.....	147
3.12.1	Mudmat Design Geometry.....	147
3.12.2	Key Design Factors	149
3.12.3	Design Procedures	150

3.13 Conclusion	153
3.14 References.....	154
4 Driven Pile Design for Tension Leg Platforms	161
4.1 Introduction	161
4.2 Pile Installation	161
4.3 Design of Piles	163
4.4 Preliminary Design Considerations.....	164
4.5 Soil Properties.....	164
4.6 Axial Capacity.....	166
4.7 Sustained (Creep) Loading.....	166
4.8 Cyclic Stresses	166
4.9 Installation Setup.....	167
4.10 Lateral Capacity	167
4.11 Installation Clearances.....	168
4.12 Installation Stability	169
4.13 Drivability and Driving Induced Fatigue Calculations	169
4.14 References.....	169
5 Pipeline Geohazards for Arctic Conditions.....	171
5.1 Ice Gouging	171
5.1.1 Introduction.....	171
5.1.2 Ice Gouge Surveys.....	174
5.1.3 Ice Gouging and Subgouge Displacements.....	175
5.1.4 Pipeline Strain Calculations.....	179
5.2 Strudel Scour.....	179
5.3 Stamukha Pits	182
5.3.1 Stamukha—Pipeline Interaction Frequency	183
5.3.2 Effect of Pits on Pipelines.....	185
5.4 References.....	187
6 The Application of Centrifuge Model Testing to Deepwater Geotechnical Problems....	189
6.1 Introduction.....	189
6.2 Principles of Centrifuge Model Testing.....	190
6.3 Previous Centrifuge Model Testing	192
6.4 Suction Caissons.....	192
6.5 Alternate Deepwater Foundation Solution	197
6.5.1 Suction Embedded Plate Anchors	197
6.5.2 Torpedo Anchors	200
6.6 Conductor Fatigue.....	205
6.7 Flowlines and Pipelines	208
6.8 Facilities, Logistics, and Rationale for Centrifuge Modeling	211
6.9 Conclusions.....	213
6.10 References.....	214
7 Reliability of Offshore Foundations.....	217
7.1 Introduction.....	217
7.2 Methods for Reliability Analysis	217
7.2.1 Simplified Analytical Models.....	219
7.2.2 Analytical Approximation—First Order Reliability Method	222
7.2.3 Numerical Approximation—Monte Carlo Simulation	233
7.3 Practical Implementation	235
7.3.1 Foundation Capacities.....	235

7.3.2	Foundation Loads	238
7.3.3	System versus Components	239
7.3.4	Target Reliability	241
7.4	Conclusion	242
7.5	References.....	243
8	Soil-pipe Interaction for Subsea Flowlines	247
8.1	Introduction	247
8.2	Design Considerations	247
8.2.1	Lateral Buckling	248
8.2.2	Flowline Walking	250
8.2.3	Upheaval Buckling	250
8.3	Analysis Methodology	251
8.3.1	Lateral Buckling	251
8.3.2	Flowline Walking	253
8.3.3	Upheaval Buckling.....	254
8.3.4	Modeling Scheme.....	254
8.4	Illustrative Examples.....	256
8.4.1	Lateral Soil-pipe Resistance	256
8.4.2	Lateral Buckling	258
8.4.3	Upheaval Buckling.....	262
8.4.4	Walking.....	262
8.5	Conclusions	265
8.5	References.....	268
9	Modeling of Soil-pipe Interaction.....	271
9.1	Introduction	271
9.2	Lateral Soil-pipe Resistance	271
9.2.1	Vertical Embedment Solution	271
9.2.2	Lateral Breakout Resistance	272
9.2.3	Lateral Residual Resistance.....	273
9.2.4	Example Lateral Resistance Model Calibration	276
9.3	Upheaval Soil-pipe Resistance	277
9.3.1	Upheaval Buckling Resistance.....	277
9.3.2	Buried Lateral Resistance.....	278
9.4	Conclusion	280
9.5	References.....	281
10	Constitutive Modeling for Geomaterials	283
10.1	Introduction	283
10.2	Critical State and Capped Plasticity Models.....	283
10.2.1	Basics of Plasticity Modeling	284
10.2.2	Geometric Representation of Stress.....	286
10.2.3	Cam-clay Model	286
10.2.4	Capped Plasticity Model	288
10.2.5	Single-surface Critical State Models	288
10.3	Traditional Strength Models	291
10.4	Recent Developments	295
10.5	Conclusion	296
10.6	References.....	297
11	Finite Element Applications.....	299
11.1	Introduction	299

Contents

11.2 Plane Strain Bearing Capacity Evaluation.....	299
11.2.1 Purely Cohesive Material	299
11.2.2 Material with Cohesion and Friction	300
11.3 Suction Pile Lateral Resistance.....	301
11.4 Torpedo Pile Penetration.....	305
11.5 Cyclic Response of Axially Loaded Piles.....	308
11.5.1 Modeling of Element States of Stress.....	314
11.5.2 Modeling with Continuum Model.....	317
11.6 Rock Mechanics Application	318
11.6.1 HISS/DSC Model Calibration for Berea Sandstone	323
11.7 Conclusion	323
11.8 References.....	324