
Contents

<i>Foreword</i>	xv
<i>Preface</i>	xvii
<i>Preface to the second edition</i>	xix
<i>Preface to the first edition</i>	xxi
<i>About the Authors</i>	xxiii
<i>List of symbols</i>	xxv
1 Introduction	1
1.1 <i>The historical context</i>	1
1.2 <i>The coastal environment</i>	3
1.2.1 <i>Context</i>	3
1.2.2 <i>Beach origins</i>	3
1.2.3 <i>Time and space scales</i>	4
1.2.4 <i>The action of waves on beaches</i>	4
1.2.5 <i>Coastal features</i>	5
1.2.6 <i>Natural bays and coastal cells</i>	6
1.2.7 <i>Coastal zone management principles</i>	9
1.2.8 <i>Coastal defence principles</i>	12
1.3 <i>Understanding coastal system behaviour</i>	12
1.3.1 <i>Introduction</i>	12
1.3.2 <i>Recognising shoreline types</i>	13
1.3.3 <i>Influences upon coastal behaviour</i>	15
1.3.4 <i>Generic questions</i>	16
1.3.4.1 <i>Past evolution</i>	16
1.3.4.2 <i>Controls and influences</i>	17
1.3.4.3 <i>Forcing</i>	17
1.3.4.4 <i>Linkages</i>	17
1.3.4.5 <i>Morphology</i>	18
1.4 <i>Scope</i>	18
<i>Further reading</i>	19
2 Wave theory	21
2.1 <i>Introduction</i>	21
2.2 <i>Small amplitude wave theory</i>	23

2.2.1	<i>Derivation of the Airy wave equations</i>	23
2.2.2	<i>Water particle velocities, accelerations and paths</i>	26
2.2.3	<i>Pressure variation induced by wave motion</i>	27
2.2.4	<i>The influence of water depth on wave characteristics</i>	28
2.2.5	<i>Group velocity and energy propagation</i>	29
2.2.6	<i>Radiation stress (momentum flux) theory</i>	30
2.3	<i>Wave transformation and attenuation processes</i>	31
2.3.1	<i>Refraction</i>	31
2.3.2	<i>Shoaling</i>	33
2.3.3	<i>Combined refraction and shoaling</i>	34
2.3.3.1	<i>Bathymetry effects on refraction</i>	37
2.3.3.2	<i>Shoaling and refraction of directional wave spectra</i>	37
2.3.4	<i>Numerical solution of the wave dispersion equation</i>	39
2.3.5	<i>Seabed friction</i>	40
2.3.6	<i>Wave-current interaction</i>	41
2.3.7	<i>The generalised refraction equations for numerical solution techniques</i>	43
2.3.8	<i>The wave conservation equation in wave ray form</i>	43
2.3.9	<i>Wave conservation equation and wave energy conservation equation in Cartesian coordinates</i>	46
2.3.10	<i>Wave reflection</i>	46
2.3.10.1	<i>Clapotis gaufre</i>	48
2.3.10.2	<i>Mach stem</i>	49
2.3.10.3	<i>Wave reflection coefficients</i>	49
2.3.10.4	<i>Predictive equations for wave reflection from rock slopes</i>	49
2.3.10.5	<i>Wave reflection due to refraction</i>	50
2.3.11	<i>Wave diffraction</i>	50
2.3.11.1	<i>Mathematical formulation of wave diffraction</i>	52
2.3.11.2	<i>Solutions to the Helmholtz equation</i>	53
2.3.12	<i>Combined refraction and diffraction</i>	54
2.4	<i>Finite amplitude waves</i>	55
2.5	<i>Wave forces</i>	56
2.5.1	<i>Vertical walls</i>	56
2.5.2	<i>Rubble mounds</i>	57
2.5.3	<i>Vertical piles</i>	57
2.6	<i>Surf zone processes</i>	61
2.6.1	<i>A general description of the surf zone</i>	61
2.6.2	<i>Wave breaking</i>	61
2.6.2.1	<i>Breaker types</i>	63
2.6.3	<i>Wave set-down and set-up</i>	65
2.6.4	<i>Radiation stress components for oblique waves</i>	67
2.6.5	<i>Longshore currents</i>	67
2.6.6	<i>Infragravity waves</i>	70
	<i>Further reading</i>	71

3 Design wave specification 73

- 3.1 *Introduction* 73
- 3.2 *Short term wave statistics* 73
 - 3.2.1 *Time domain analysis* 73
 - 3.2.2 *Frequency domain analysis* 79
- 3.3 *Directional wave spectra* 81
- 3.4 *Wave energy spectra, the JONSWAP spectrum* 84
 - 3.4.1 *Bretschneider Spectrum* 86
 - 3.4.2 *Pierson-Moskowitz Spectrum* 86
 - 3.4.3 *JONSWAP spectrum* 87
- 3.5 *Swell waves* 88
- 3.6 *Prediction of deep water waves* 90
- 3.7 *Prediction of nearshore waves* 92
 - 3.7.1 *Point prediction of wind-generated waves* 92
 - 3.7.2 *The SMB method* 93
 - 3.7.3 *The JONSWAP method* 93
 - 3.7.4 *Further modifications and automated methods* 95
 - 3.7.4.1 *Saville's method* 95
 - 3.7.4.2 *Seymour's method* 95
 - 3.7.4.3 *Donelan-JONSWAP method* 95
 - 3.7.4.4 *SMB shallow water formulae* 95
 - 3.7.4.5 *Automated methods* 96
- 3.8 *The TMA spectrum* 97
- 3.9 *Accounting for swell* 98
- 3.10 *Numerical transformation of deep water wave spectra* 99
 - 3.10.1 *Spectral ray models* 101
 - 3.10.2 *Mild-slope equation* 102
 - 3.10.3 *Nonlinear models* 104
- 3.11 *Choosing and defining design conditions* 105
- 3.12 *Long-term wave climate changes* 107
- Further reading* 109

4 Coastal water level variations 111

- 4.1 *Introduction* 111
- 4.2 *Astronomical tide generation* 112
 - 4.2.1 *Diurnal inequality* 117
 - 4.2.2 *Tidal species* 118
 - 4.2.3 *Spring-neap tidal variation* 119
 - 4.2.4 *Tidal ratio* 120
- 4.3 *Tide measurements* 122
 - 4.3.1 *Sea surface as a levelling datum* 125
- 4.4 *Harmonic analysis* 127
- 4.5 *Numerical prediction of tides* 129
- 4.6 *Theory of long-period waves* 129
- 4.7 *Tidal flow modelling* 133

4.8	Storm surge	142
4.8.1	Storm surge components	142
4.8.2	Basic dynamic storm surge equations	147
4.8.3	Numerical forecasting of storm surge	148
4.8.4	Oscillations in simple basins	149
4.9	Tsunamis	152
4.9.1	The Indian Ocean tsunami: 26 December 2004	156
4.9.2	The South Pacific Islands tsunami: 29 September 2009	158
4.9.3	The Japan tsunami: 11 March 2011	159
4.10	Long-term water level changes	161
4.10.1	Climatic fluctuations	161
4.10.2	Eustatic component	162
4.10.3	Isostatic component	163
4.10.4	Global climate change	163
	Further reading	166

5 Coastal transport processes

167

5.1	Characteristics of coastal sediments	167
5.2	Sediment transport	168
5.2.1	Modes of transport	168
5.2.2	Description of the threshold of movement	170
5.2.3	Bedforms	171
5.2.4	Estimation of bed shear stress	172
5.2.4.1	Current skin friction bed shear stress	172
5.2.4.2	Current generated ripples and dunes	173
5.2.4.3	Current total bed shear stress	173
5.2.4.4	Wave skin friction shear stress	174
5.2.4.5	Wave generated ripples	174
5.2.4.6	Wave total shear stress	175
5.2.4.7	Bed shear stress under waves and currents	175
5.2.5	The entrainment function (Shields parameter)	175
5.2.6	Bed load transport equations	178
5.2.6.1	Currents	178
5.2.6.2	Waves	178
5.2.6.3	Waves and currents	178
5.2.7	A general description of the mechanics of suspended sediment transport	180
5.2.7.1	The mechanics of particle suspension	180
5.2.8	Suspended sediment concentration under currents	183
5.2.9	Suspended sediment concentration under waves and waves with currents	188
5.2.10	Total load transport formulae	189
5.2.10.1	General approach	189
5.2.10.2	Total load transport by currents	189
5.2.10.3	Ackers and White formula (White 1972) and in revised form in Ackers (1993)	189

5.2.10.4	<i>van Rijn (1984)</i>	190
5.2.10.5	<i>Total load transport by waves and waves plus currents</i>	193
5.2.11	<i>Cross-shore transport on beaches</i>	194
5.2.12	<i>Longshore transport ('littoral drift')</i>	195
5.2.12.1	<i>General description</i>	195
5.2.12.2	<i>Estimating longshore transport</i>	195
5.2.12.3	<i>Longshore sediment transport equations</i>	195
5.2.13	<i>Concluding notes on sediment transport</i>	201
	<i>Further reading</i>	201

6 Coastal morphology: Analysis, modelling and prediction 203

6.1	<i>Introduction</i>	203
6.1.1	<i>Baseline review</i>	204
6.2	<i>Beach profiles</i>	207
6.2.1	<i>Analysis of beach profile measurements</i>	207
6.2.2	<i>The empirical orthogonal function technique</i>	207
6.2.3	<i>Other methods</i>	210
6.2.4	<i>Equilibrium profiles and the depth of closure</i>	212
6.2.4.1	<i>The Bruun rule for beach erosion resulting from sea level rise</i>	217
6.2.5	<i>Numerical prediction of beach profile response</i>	217
6.2.5.1	<i>Statistical methods</i>	217
6.2.5.2	<i>Parametric methods</i>	220
6.2.6	<i>Shingle beaches</i>	220
6.2.7	<i>Barrier beach processes</i>	221
6.2.8	<i>Dune erosion</i>	222
6.2.8.1	<i>Morphological methods</i>	224
6.2.8.2	<i>Deterministic process models</i>	225
6.3	<i>Beach plan shape</i>	226
6.3.1	<i>Plan shape measurements</i>	226
6.3.2	<i>Equilibrium forms</i>	228
6.3.3	<i>Beach plan shape evolution equation</i>	228
6.3.4	<i>Analytical solutions</i>	231
6.3.4.1	<i>Analytical solutions</i>	232
6.3.5	<i>Numerical solutions</i>	236
6.3.6	<i>Discretisation</i>	236
6.3.6.1	<i>Convergence</i>	238
6.3.6.2	<i>Accuracy</i>	238
6.3.6.3	<i>Stability</i>	238
6.4	<i>Nearshore morphology</i>	241
6.4.1	<i>Introduction</i>	241
6.4.2	<i>EOF methods for beaches and the nearshore bathymetry</i>	242
6.4.3	<i>Combined wave, tide and sediment transport models</i>	244
6.5	<i>Long-term prediction</i>	246
6.5.1	<i>Limits on predictability</i>	246

6.5.1.1	<i>Phase space reconstruction</i>	251
6.5.2	<i>Probabilistic methods</i>	251
6.5.3	<i>Systems approach</i>	255
	<i>Further reading</i>	256
7	Design, reliability and risk	257
7.1	<i>Design conditions</i>	257
7.1.1	<i>Introduction</i>	257
7.1.2	<i>Extreme values and return period</i>	257
7.1.3	<i>Distribution of extreme values</i>	262
7.1.3.1	<i>Probability plots</i>	265
7.1.4	<i>Calculation of marginal extremes</i>	267
7.1.4.1	<i>Graphical procedures</i>	268
7.1.4.2	<i>The method of moments</i>	274
7.1.4.3	<i>Method of maximum likelihood</i>	274
7.1.5	<i>Dependence and joint probability</i>	276
7.2	<i>Reliability and risk</i>	280
7.2.1	<i>Risk assessment</i>	280
7.2.1.1	<i>Functional analysis</i>	283
7.2.1.2	<i>Reliability block diagram (RBD)</i>	283
7.2.1.3	<i>Tiered approach</i>	287
7.2.2	<i>Structures, damage mechanisms and modes of failure</i>	287
7.2.2.1	<i>Reported damage and failures</i>	289
7.2.3	<i>Assessing the reliability of structures</i>	293
7.2.4	<i>Level I methods</i>	295
7.2.5	<i>Level II methods</i>	296
7.2.5.1	<i>Mean value approach (MVA)</i>	299
7.2.5.2	<i>Design point approach (FDA)</i>	302
7.2.5.3	<i>Approximate full distribution approach (AFDA)</i>	304
7.2.5.4	<i>Point moment techniques</i>	304
7.2.6	<i>Level III methods</i>	306
7.2.7	<i>Accounting for dependence</i>	308
7.2.7.1	<i>Correlated normal variables</i>	309
7.2.7.2	<i>Non-normal marginals with known correlation matrix</i>	311
7.2.8	<i>Accounting for uncertainty</i>	312
	<i>Further reading</i>	313
8	Field measurements and physical models	315
8.1	<i>The need for field measurements and physical models</i>	315
8.2	<i>Field investigations</i>	316
8.3	<i>Theory of physical models</i>	316
8.3.1	<i>Generic model types</i>	316
8.3.2	<i>Similitude</i>	332
8.4	<i>Short wave hydrodynamic models</i>	334

- 9.1 *The wider context of design* 343
 - 9.1.1 *Pressures on the coast* 343
 - 9.1.1.1 *Local approaches* 343
 - 9.1.1.2 *Strategic approaches* 344
 - 9.1.2 *Early strategic approach in the UK (Case Study)* 345
 - 9.1.3 *Current UK SMP approach (2011)* 347
 - 9.1.4 *Adaptation to climate change* 351
 - 9.1.4.1 *An example of adaptation to climate change in Barbados (Case Study)* 351
- 9.2 *Coastal structures* 351
 - 9.2.1 *Groynes* 356
 - 9.2.2 *Shore-connected breakwaters* 364
 - 9.2.3 *Detached breakwaters* 369
 - 9.2.4 *Port and harbour breakwaters* 373
 - 9.2.5 *Floating breakwaters* 378
 - 9.2.6 *Sea walls* 379
 - 9.2.7 *Sills* 382
- 9.3 *Natural coastal structures* 383
 - 9.3.1 *Beach nourishment* 384
 - 9.3.2 *Dune management* 386
 - 9.3.3 *Tidal flats and marshes* 388
- 9.4 *Design guidance notes* 390
 - 9.4.1 *Wave run-up* 392
 - 9.4.2 *Wave overtopping and crest elevation* 394
 - 9.4.2.1 *Calculation of overtopping rates* 395
 - 9.4.2.2 *EurOtop methods* 402
 - 9.4.2.3 *Vertical and steep sea walls* 407
 - 9.4.2.4 *Wave transmission by overtopping* 408
 - 9.4.2.5 *The new EurOtop database (2016)* 410
 - 9.4.2.6 *The new EurOtop artificial neural network (2016)* 410
 - 9.4.2.7 *Designing for overtopping* 411
 - 9.4.3 *Armour slope stability* 412
 - 9.4.3.1 *Rock armour slopes* 413
 - 9.4.3.2 *Dynamically stable armouring* 419
 - 9.4.3.3 *Mass concrete armour unit slopes* 419
 - 9.4.3.4 *Energy dissipating armour units* 422
 - 9.4.3.5 *Other revetment protection systems* 423
 - 9.4.3.6 *Port and harbour breakwaters* 424
 - 9.4.3.7 *Structure roundheads and transitions* 426
 - 9.4.4 *Crest and lee slope armour* 427

9.4.5	<i>Rock grading</i>	428
9.4.6	<i>Underlayers and internal stability</i>	430
9.4.6.1	<i>Primary underlayer</i>	431
9.4.6.2	<i>Filter rules</i>	433
9.4.6.3	<i>Geotextiles</i>	434
9.4.7	<i>Crown walls</i>	436
9.4.8	<i>Scour and toe stability</i>	436
9.4.8.1	<i>Selection of toe protection</i>	437
9.4.8.2	<i>Armoured toe design</i>	439
9.4.8.3	<i>Vertically faced structures</i>	443
9.4.8.4	<i>General considerations</i>	443
9.4.9	<i>Design of sea walls</i>	444
9.4.10	<i>Beach nourishment design</i>	446
9.5	<i>Design example</i>	450
9.5.1	<i>Design criteria</i>	451
9.5.1.1	<i>Wave breaking according to Goda (2000)</i>	451
9.5.2	<i>Design of the armour rocks</i>	452
9.5.2.1	<i>Methodology</i>	452
9.5.2.2	<i>Design parameters</i>	452
9.5.2.3	<i>Design procedure and results</i>	452
9.5.3	<i>Crest level and configuration</i>	453
9.5.3.1	<i>Overtopping</i>	454
9.5.4	<i>Design of underlayer</i>	455
9.5.4.1	<i>Checking for filter rules</i>	456
9.5.5	<i>Thickness of layers</i>	457
9.5.6	<i>Design of toe</i>	458
<i>Appendix A: Summary of statistical concepts and terminology</i>		459
<i>Appendix B: Maximum likelihood estimation</i>		465
<i>Appendix C: Harmonic analysis results</i>		471
<i>Appendix D: Normal distribution tables</i>		477
<i>References</i>		483
<i>Index</i>		505