

PROCEEDINGS OF THE SHORT COURSE ON COASTAL PROTECTION  
DELFT UNIVERSITY OF TECHNOLOGY / 30 JUNE-1 JULY 1990

# Coastal Protection

*Edited by*

KRYSTIAN W. PILARCZYK

*Rijkswaterstaat, Delft*



A.A. BALKEMA / ROTTERDAM / BROOKFIELD / 1990



# Table of contents

Introduction to coastal protection <i>Krystian W. Pilarczyk</i>	1
General strategy on coastline protection – The Dutch case <i>Cees Louisse &amp; Henk Jan Verhagen</i>	15
Probabilistic design of flood defences <i>J.K. Vrijling</i>	39
Dune and beach erosion and nourishment <i>Jan van de Graaff &amp; Maarten J. Koster</i>	99
Principles and effectiveness of Groynes <i>C.A. Flemming</i>	121
Static and dynamic stability of loose materials <i>Jentsje W. van der Meer</i>	157
Design of seawalls and dikes – Including overview of revetments <i>Krystian W. Pilarczyk</i>	197
Placed block revetments <i>Adam Bezuijen, Mark Klein Breteler &amp; André Burger</i>	289
Asphalt mixtures for revetments of water defences and embankments <i>J.A. van Herpen</i>	327
Maintenance and monitoring of water retaining structures <i>Louis de Quelerij &amp; Ep van Hijum</i>	369
Appendixes	
Data collection and prediction methods – An overview <i>Krystian W. Pilarczyk</i>	405

Hydraulic boundary conditions related to the design of the Oosterschelde Storm Surge Barrier in the Netherlands — An example of a joint distribution of waves and surges <i>J.K.Vrijling &amp; J.Bruinsma</i>	423
Random seas for design of maritime structures <i>Yoshimi Goda</i>	447
Dutch research strategy on water defences <i>Krystian W.Pilarczyk</i>	483
List of contributors	499

## Extended table of contents

1 INTRODUCTION TO COASTAL PROTECTION	1
<i>K.W.Pilarczyk</i>	
1 Introduction	1
1.1 General	1
1.2 Review of coastal defence methods	3
1.3 Design considerations and methodology	4
1.4 Design process of coastal structures	6
1.5 Structural aspects and design procedure checklist	10
References	13
2 GENERAL STRATEGY ON COASTLINE PROTECTION – THE DUTCH CASE	15
<i>Cees Louisse &amp; Henk Jan Verhagen</i>	
1 Introduction	15
1.1 The Dutch coast	15
1.2 Legal framework for the coastal defence system	17
1.3 Need for a coastal defence policy in the Netherlands	19
1.4 History	20
1.5 Changes in dune appraisal	20
1.6 Finance	21
1.7 Strategy	21
2 Problem of the coast	22
2.1 Causes of coastal erosion	22
2.2 Impact of sea level rise	24
2.3 Impact of chronic erosion on safety	24
2.4 Impact of chronic erosion on other functions in the dune area	25
2.5 Impact of shoreline retreat on values on the beach	26
3 Alternatives for coastal defence	27
3.1 Withdrawal	27
3.2 Selective erosion control	28
3.3 Full erosion control	28
3.4 Seaward expansion	28

4 Method of analysis	29
5 Effects of coastal defence alternatives	30
References	35
<b>3 PROBABILISTIC DESIGN OF FLOOD DEFENCES</b>	<b>39</b>
<i>J.K.Vrijling</i>	
1 Introduction and historical background	39
1.1 Introduction	39
1.2 Historical background	39
2 General design approach	42
3 The storm-surge-barrier	51
3.1 Introduction	51
3.2 The hydraulic boundary conditions	52
3.3 The probabilistic load determination	54
3.4 Probabilistic design procedures	55
3.5 The fault-tree analysis	58
3.6 Risk analysis of construction and cost	60
3.7 Conclusions	62
4 Probabilistic dike design	62
4.1 Introduction	62
4.2 System description	62
4.3 Failure mechanisms	63
4.4 Risk analysis of the system by means of the fault-tree approach	66
4.5 Evaluation of the probability of failure	68
5 Assessment of risk levels	73
5.1 General	73
5.2 Personally acceptable level of risk	73
5.3 Socially acceptable level of risk	76
5.4 A concept of acceptable risk	86
6 Sea-level rise: A probabilistic design problem	89
6.1 Introduction	89
6.2 An economic model	89
6.3 Conclusions	95
7 Conclusions	95
References	96
<b>4 DUNE AND BEACH EROSION AND NOURISHMENT</b>	<b>99</b>
<i>Jan van de Graaff &amp; Maarten J. Koster</i>	
1 Introduction	99
2 Causes of coastal erosion	99
2.1 General	99
2.2 Loss due to structural erosion	100
2.3 Loss due to a severe storm (surge)	104
3 Dune erosion calculation methods	106
3.1 Introduction	106
3.2 The shape of the expected erosion profile	108

3.3	Discrepancy between real erosion profile and expected erosion profile	109
3.4	Recipe for a probabilistic calculation	109
3.5	The probabilistic calculation	110
3.6	Safety against severe damage due to inundation	112
3.7	A simplified model	112
3.8	A more sophisticated time dependent model	113
3.9	State of the art with respect to the models	114
3.10	Case studies and demonstration of the models	114
4	Counter-measures	115
4.1	General	115
4.2	Methods to combat structural erosion	115
4.3	Methods to combat the loss during a severe storm (surge)	118
5	References	120
5	PRINCIPLES AND EFFECTIVENESS OF GROYNES	121
	<i>C.A. Flemming</i>	
1	Introduction	121
2	The coastal environment	125
2.1	Topography and bathymetry	125
2.2	Geology and beach classification	127
2.3	Water level	127
2.4	Wave conditions	129
2.5	Nearshore currents	130
2.6	Stability of the foreshore	131
3	Application of groynes in UK experience	133
3.1	General objectives	133
3.2	Effects of groynes on beach shape	133
3.3	Effects of groynes and nearshore currents	134
4	Design of groyne layout – UK practice	135
4.1	Beach profiles	135
4.2	Beach plan shape between groynes	136
4.3	Alongshore drift	136
4.4	Groyne height	136
4.5	Groyne length	137
4.6	Groyne spacing	138
4.7	Inclination of groyne to coastline	139
4.8	Terminal groyne	139
4.9	Downdrift scour	139
4.10	Beach head	140
4.11	Beach nourishment	140
4.12	Maintenance requirements	142
4.13	Design notes related to specific beach and groyne type	142
5	Groynes in coastal engineering – Netherlands experience	145
5.1	Introduction	145
5.2	Hydraulic factors	145

5.3 Conclusions	148
6 Detached breakwaters and artificial headlands	149
6.1 Introduction	149
6.2 Detached breakwaters	149
6.3 Artificial headlands	150
References	151
Bibliography	154
<b>6 STATIC AND DYNAMIC STABILITY OF LOOSE MATERIALS</b>	<b>157</b>
<i>Jentsje W. van der Meer</i>	
1 Introduction	157
1.1 Processes involved in coastal protection structures	157
1.2 Classification of coastal structures	159
2 Structural parameters	161
2.1 Structural parameters related to waves	161
2.2 Structural parameters related to rock	163
2.3 Structural parameters related to the cross-section	164
2.4 Structural parameters related to the response of the structure	165
3 Introduction to structural response	167
4 Rock armour layers	169
5 Armour layers with concrete units	176
6 Low-crested structures	178
6.1 Reef breakwater (Fig. 17A)	180
6.2 Statically stable low-crested breakwaters (Fig. 17B)	180
6.3 Submerged breakwaters (Fig. 17C)	182
7 Dynamically stable slopes (berm breakwaters)	182
8 Stepped and composite slopes	185
9 Underlayers and filters	187
10 Toe protection	188
11 Breakwater head	189
12 Longshore transport of coarse materials	191
References	194
<b>7 DESIGN OF SEAWALLS AND DIKES – INCLUDING OVERVIEW OF REVETMENTS</b>	<b>197</b>
<i>Krzysztof W. Pilarczyk</i>	
1 Introduction	197
1.1 General	197
1.2 Functions	198
1.3 Starting-points for the design	198
2 Effects of seawalls/dikes on the beach	200
2.1 General	200
2.2 Physical interactions and consequences	201
2.3 Literature review	204
3 Conceptual design	209
3.1 General	209

3.2 The functional design	209
3.3 The structural design	209
4 Design philosophy	211
5 Seawall and dike design	214
5.1 Boundary conditions	214
5.1.1 Assessment of the existing situation	214
5.1.2 Hydraulic boundary conditions	214
5.1.3 Geotechnical conditions	217
5.1.4 Construction materials	218
5.2 Shape and height of a seawall/dike	218
5.2.1 Loading zones	218
5.2.2 Wave-structure interaction	220
5.2.3 Dike shape	221
5.2.4 Dike height; wave run-up and overtopping	222
5.2.4.1 General consideration on the height of a dike	222
5.2.4.2 Wave run-up	223
5.2.4.3 Wave overtopping	226
5.3 Geotechnical aspects	231
5.3.1 General	231
5.3.2 Geotechnical limit states	233
6 Revetments	235
6.1 General requirements	235
6.2 Type of revetments	235
6.3 Choice of revetments	236
6.4 Load-strength concept	236
6.4.1 General approach	236
6.4.2 Failure modes and determinant load	238
6.5 Dimensioning	240
6.6 Principles of composition	241
6.7 Subsoil requirements	241
7 Hydraulic stability criteria for materials and systems	243
7.1 General	243
7.2 Stability criteria for wave attack	244
7.3 Stability criteria for current attack	251
7.4 Filter constructions	260
7.4.1 General	260
7.4.2 Granular filters	260
7.4.3 Filter rules	261
7.4.4 Geotextile filters	262
7.4.5 Materials demands	264
7.5 Investigation on grass slopes	264
8 Semi-probabilistic calculation of revetments	265
9 Structure related demands	270
9.1 Slope protection	270
9.2 Optimization of slope stability	270



9.3 Scour protection	272
9.4 Protection against overtopping	277
9.5 Joints and transitions	281
10 Management and monitoring	282
11 Conclusions and recommendations	283
References	286
<b>8 PLACED BLOCK REVETMENTS</b>	<b>289</b>
<i>Adam Bezuijen, Mark Klein Breteler &amp; André Burger</i>	
1 Introduction	289
2 Failure mechanisms	290
2.1 Introduction	290
2.2 Overall loading on the revetment	291
2.3 Failure mechanisms for the various components	292
2.3.1 Cover layer	292
2.3.2 Filter layer	293
2.3.3 Subsoil	294
3 Hydraulic boundary conditions	295
3.1 Wave height	295
3.2 Wave pressures	295
3.3 Wave run-up and wave run-down	297
4 Stability of cover layer	298
4.1 Loading by wave pressures and pore pressures	298
4.2 Uplift and sliding	303
4.2.1 Lifting of blocks	304
4.2.2 Sliding of the cover layer	308
5 Stability of the filter layer	311
5.1 Loading on the filter layer	311
5.2 Internal stability	312
5.3 Filter stability	312
6 Stability of the subsoil	314
7 Permeabilities	319
7.1 Permeability of granular material	319
7.2 Permeability of placed blocks	320
7.3 Permeability of geotextiles	323
7.4 Linearized permeabilities	323
7.5 Accuracy of permeability determinations	324
8 Conclusions	324
References	325
<b>9 ASPHALT MIXTURES FOR REVETMENTS OF WATER DEFENCES AND EMBANKMENTS</b>	<b>327</b>
<i>J.A. van Herpen</i>	
1 Introduction	327
2 Applications	327
3 Hydraulic asphaltic mixtures	330

3.1	General	330
3.2	Asphaltic concrete	333
3.3	Asphaltic mastic	335
3.4	Grouting mortars	337
3.5	Open stone asphalt	337
3.6	Lean sand asphalt	339
4	Initial design	339
5	Final design	342
5.1	General	342
5.2	The dike body	342
5.3	Design on hydraulic uplift pressures	343
5.4	Design of a plate-type asphalt revetment against wave impacts	348
5.5	Design of a surface- or pattern-grouted stone layer against wave attack	353
5.6	Design of underwater bed protection against hydraulic uplift pressures caused by waves	355
5.7	Design of an asphalt revetment against currents	356
6	Execution	358
6.1	General aspects	358
6.2	Asphaltic concrete	359
6.3	Mastic	362
6.4	Grouting mortars	363
6.5	Open stone asphalt	363
6.6	Lean sand asphalt	364
6.7	Joints in bituminous revetments	365
	References	367
10	MAINTENANCE AND MONITORING OF WATER RETAINING STRUCTURES	369
	<i>Louis de Quelerij &amp; Ep van Hijum</i>	
1	Introduction	369
2	Management of maintenance	369
2.1	Goal	369
2.2	Actual situation	370
2.3	Inventory of skills	371
2.4	Management scheme	372
2.4.1	Objectives and elements	372
2.4.2	Data-base/register	372
2.4.3	Management policy plan	373
2.4.4	REC-assessment model	374
2.4.5	Annual budget estimate	376
2.4.6	Maintenance plan	377
2.4.7	Annual account	379
2.4.8	Justification reports	380
3	Management scheme for flood control in the Netherlands	380
4	Maintenance and monitoring system for dikes	381

4.1 General conceptions	381
4.2 Set up of safety control system	385
4.2.1 Rough description of dike elements and boundary conditions	385
4.2.2 Relative strength with respect to ultimate failure	386
4.2.3 Relative importance of deterioration mechanisms	386
4.2.4 Decisive dike sections and dike clusters	388
4.2.5 Damage patterns and failure limits per dike cluster	388
4.2.6 Inspection and monitoring strategy	392
4.2.7 Scheme for repair measures	394
5 Case study Hondsbossche seadike	395
5.1 Project description	395
5.2 Selection of decisive dike sections and clusters	397
5.3 Selection of damage patterns and damage limits	398
5.4 Assessment scheme for inspection and repair measures	400
5.5 Evaluation	401
Acknowledgement	401
Literature	401
 Data collection and prediction methods – An overview	 405
<i>Krystian W. Pilarczyk</i>	
 Hydraulic boundary conditions related to the design of the Oosterschelde	 423
Storm Surge Barrier in the Netherlands – An example of a joint distribution of	
waves and surges	
<i>J.K. Vrijling &amp; J. Bruinsma</i>	
 Random seas for design of maritime structures	 447
<i>Yoshimi Goda</i>	
 Dutch research strategy on water defences	 483
<i>Krystian W. Pilarczyk</i>	
 List of contributors	 499