

Contents

List of Recommendations in the 9th Edition	XXI
Preface to 11th, revised edition (9th English edition) of the <i>Recommendations of the Committee for Waterfront Structures – Harbours and Waterways</i>	XXVII
0 Structural calculations	1
0.1 General	1
0.2 Safety concept	2
0.2.1 General	2
0.2.2 Combination factors	7
0.2.3 Analysis of ultimate limit state	8
0.2.4 Analysis of serviceability limit state	9
0.2.5 Geotechnical categories	9
0.2.6 Probabilistic analysis	9
0.3 Calculations for waterfront structures	10
1 Subsoil	11
1.1 Mean characteristic values of soil parameters (R 9)	11
1.1.1 General	11
1.2 Layout and depths of boreholes and penetrometer tests (R 1)	11
1.2.1 General	11
1.2.2 Principal boreholes	17
1.2.3 Intermediate boreholes	17
1.2.4 Penetrometer tests	17
1.3 Geotechnical report (R 150)	18
1.4 Determining the shear strength c_u of saturated, undrained cohesive soils (R 88)	19
1.4.1 Cohesion c_u of undrained soil	19
1.4.2 Determining the cohesion c_u of an undrained soil	20
1.4.3 Determining c_u in laboratory tests	21
1.4.4 Field tests	22
1.4.5 Correlations	22
1.5 Assessing the subsoil for the installation of piles and sheet piles and for selecting the installation method (R 154)	22
1.5.1 General	22
1.5.2 Assessment of soil types with respect to installation methods	23

2	Active and passive earth pressure	27
2.1	General	27
2.2	Considering the cohesion in cohesive soils (R 2)	27
2.3	Considering the apparent cohesion (capillary cohesion) in sand (R 3)	27
2.4	Determining active earth pressure according to the Culmann method (R 171)	28
2.4.1	Solution for uniform soil without cohesion	28
2.4.2	Solution for uniform soil with cohesion	29
2.4.3	Expanded solutions	29
2.5	Active earth pressure in stratified soil (R 219)	30
2.6	Determining active earth pressure for a steep, paved embankment in a partially sloping waterfront structure (R 198)	32
2.7	Determining the active earth pressure shielding on a wall below a relieving platform with average ground surcharges (R 172)	34
2.8	Earth pressure distribution under limited loads (R 220)	37
2.9	Determining active earth pressure in saturated, non- or partially consolidated, soft cohesive soils (R 130)	38
2.10	Effect of artesian water pressure under harbour bottom or river bed on active and passive earth pressures (R 52)	40
2.11	Considering active earth pressure and excess water pressure, and construction guidance for waterfront structures with soil replacement and contaminated or disturbed base of excavation (R 110)	42
2.11.1	General	42
2.11.2	Approach for determining active earth pressure	42
2.11.3	Approaches for determining excess water pressure	44
2.11.4	Guidance for the design of waterfront structures	44
2.12	Effect of groundwater flow on excess water pressure and active and passive earth pressures (R 114)	46
2.12.1	General	46
2.12.2	Determining the excess water pressure	48
2.12.3	Determining the effects on active and passive earth pressures when the flow is mainly vertical	50
2.13	Determining the amount of displacement required for mobilising passive earth pressure in non-cohesive soils (R 174)	53
2.14	Measures for increasing the passive earth pressure in front of waterfront structures (R 164)	54
2.14.1	General	54
2.14.2	Soil replacement	55
2.14.3	Soil compaction	55
2.14.4	Soil surcharge	56
2.14.5	Soil stabilisation	56
2.15	Passive earth pressure in front of abrupt changes in ground level in soft cohesive soils with rapid load application on land side (R 190)	57

2.16	Waterfront structures in seismic regions (R 124)	57
2.16.1	General	57
2.16.2	Effects of earthquakes on the subsoil	59
2.16.3	Determining the effects of earthquakes on active and passive earth pressures	59
2.16.4	Excess water pressure	62
2.16.5	Transient loads	62
2.16.6	Design situation and partial safety factors.	62
2.16.7	Guidance for considering seismic influences on waterfront structures	62
3	Hydraulic heave failure, ground failure	64
3.1	Safety against hydraulic heave failure (R 115)	64
3.2	Piping (ground failure due to internal erosion) (R 116)	70
4	Water levels, water pressure, drainage	73
4.1	Mean groundwater level (R 58)	73
4.2	Excess water pressure in direction of water side (R 19).	73
4.3	Excess water pressure on sheet piling in front of embankments below elevated platforms in tidal areas (R 65)	75
4.3.1	General	75
4.3.2	Approximation for excess water pressure	76
4.4	Design of weepholes for sheet piling structures (R 51)	76
4.5	Design of drainage systems for waterfront structures in tidal areas (R 32)	78
4.5.1	General	78
4.5.2	Design, installation and maintenance of drainage systems.	79
4.5.3	Drainage systems for large waterfront structures.	79
4.6	Relieving artesian pressure beneath harbour bottoms (R 53)	80
4.6.1	General	80
4.6.2	Design of relief wells.	80
4.6.3	Construction of relief wells	81
4.6.4	Checking the relief installation	81
4.7	Taking account of groundwater flow (R 113)	81
4.7.1	General	81
4.7.2	Principles of groundwater flow.	81
4.7.3	Definition of the boundary conditions for a flow net.	83
4.7.4	Graphic method for determining a flow net.	83
4.7.5	Use of groundwater models to determine flow nets.	84
4.7.6	Calculation of individual hydraulic variables	85
4.7.7	Evaluation of examples	85
4.8	Temporary stabilisation of waterfront structures by groundwater lowering (R 166)	90

4.8.1	General	90
4.8.2	Case with soft, cohesive soil near the ground surface	90
4.8.3	Case as for section 4.8.2 but with high-level aquifer	92
4.8.4	Consideration of intermediate states	92
5	Ship dimensions and loads on waterfront structures	93
5.1	Ship dimensions (R 39)	93
5.1.1	Sea-going ships	93
5.1.2	River- and sea-going vessels	99
5.1.3	Inland waterway vessels.	100
5.1.4	Displacement.	103
5.2	Berthing force of ships at quays (R 38)	103
5.3	Berthing velocities of ships transverse to berth (R 40)	103
5.4	Design situations (R 18).	105
5.4.1	Design situation DS-P	105
5.4.2	Design situation DS-T	105
5.4.3	Design situation DS-A	105
5.4.4	Extreme case	106
5.5	Vertical imposed loads (R 5)	106
5.5.1	General	106
5.5.2	Basic situation 1	108
5.5.3	Basic situation 2	108
5.5.4	Basic situation 3	109
5.5.5	Loading assumptions for quay surfaces	109
5.6	Determining the “design sea state” for maritime and port structures (R 136)	110
5.6.1	General	110
5.6.2	Description of the sea state.	110
5.6.3	Determining the sea state parameters	111
5.6.4	Design concepts and specification of design parameters	116
5.6.5	Conversion of the sea state.	117
5.7	Wave pressure on vertical quay walls in coastal areas (R 135)	120
5.7.1	General	120
5.7.2	Loads due to non-breaking waves	120
5.7.3	Loads due to waves breaking on structure	121
5.7.4	Loads due to broken waves	124
5.7.5	Additional loads caused by waves	124
5.8	Loads arising from surging and receding waves due to the inflow or outflow of water (R 185)	125
5.8.1	General	125
5.8.2	Determining wave values	125
5.8.3	Load assumptions	126
5.9	Effects of waves due to ship movements (R 186)	126

5.9.1	General	126
5.9.2	Wave heights	128
5.10	Wave pressure on piled structures (R 159)	129
5.10.1	General	129
5.10.2	Method of calculation according to Morison et al.	133
5.10.3	Determining the wave loads on a single vertical pile.	134
5.10.4	Coefficients C_D and C_M	135
5.10.5	Forces from breaking waves	136
5.10.6	Wave load on a group of piles	136
5.10.7	Raking piles	137
5.10.8	Safety factors	138
5.10.9	Vertical wave load (“wave slamming”)	138
5.11	Wind loads on moored ships and their influence on the dimensioning of mooring and fender equipment (R 153)	145
5.11.1	General	145
5.11.2	Critical wind speed	145
5.11.3	Wind loads on moored vessels	145
5.11.4	Loads on mooring and fender equipment	146
5.12	Layout of and loads on bollards for sea-going vessels (R 12)	147
5.12.1	Layout	147
5.12.2	Loads	148
5.12.3	Direction of bollard pull force	148
5.13	Layout, design and loading of bollards for inland facilities (R 102)	149
5.13.1	Layout and design	149
5.13.2	Loads	150
5.13.3	Direction of line pull forces	151
5.13.4	Calculations	151
5.14	Quay loads from cranes and other transhipment equipment (R 84)	151
5.14.1	Typical general cargo port cranes	151
5.14.2	Container cranes	152
5.14.3	Load specifications for port cranes	153
5.14.4	Notes	155
5.15	Impact and pressure of ice on waterfront structures, fenders and dolphins in coastal areas (R 177)	155
5.15.1	General	155
5.15.2	Determining the compressive strength of the ice	157
5.15.3	Ice loads on waterfront structures and other structures of greater extent	158
5.15.4	Ice loads on vertical piles	161
5.15.5	Horizontal ice load on group of piles	162
5.15.6	Ice surcharges	162
5.15.7	Vertical loads with rising or falling water levels	163
5.16	Impact and pressure of ice on waterfront structures, piers and dolphins at inland facilities (R 205)	164
5.16.1	General	164

5.16.2	Ice thickness	164
5.16.3	Compressive strength of the ice	165
5.16.4	Ice loads on waterfront structures and other structures of greater extent	165
5.16.5	Ice loads on narrow structures (piles, dolphins, bridge and weir piers, ice deflectors)	166
5.16.6	Ice loads on groups of structures	166
5.16.7	Vertical loads with rising or falling water levels	167
5.17	Loads on waterfront structures and dolphins caused by fender reaction forces (R 213)	167
6	Configuration of cross-sections and equipment for waterfront structures	168
6.1	Standard cross-section dimensions for waterfront structures in seaports (R 6)	168
6.1.1	Standard cross-sections	168
6.1.2	Walkways (towpaths)	168
6.1.3	Railings, rubbing strips and edge protection	169
6.1.4	Edge bollards	169
6.1.5	Arrangement of tops of quay walls at container terminals	169
6.2	Top edges of waterfront structures in seaports (R 122)	170
6.2.1	General	170
6.2.2	Level of port operations area with regard to water levels	170
6.2.3	Effects of (changing) groundwater levels on the terrain and the level of the port operations area	171
6.2.4	Level of port operations area depending on cargo handling	171
6.3	Standard cross-sections for waterfront structures in inland ports (R 74)	172
6.3.1	Port operations level	172
6.3.2	Waterfront	172
6.3.3	Clearance profile	173
6.3.4	Position of outboard crane rail	173
6.3.5	Mooring equipment	175
6.4	Sheet piling waterfronts on inland waterways (R 106)	175
6.4.1	General	175
6.4.2	Stability analysis	177
6.4.3	Loading assumptions	177
6.4.4	Embedment depth	178
6.5	Upgrading partially sloped waterfronts in inland ports with large water level fluctuations (R 119)	178
6.5.1	Reasons for partially sloped upgrades	178
6.5.2	Design principles	178
6.6	Design of waterfront areas in inland ports according to operational aspects (R 158)	180

6.6.1	Requirements	180
6.6.2	Design principles	181
6.6.3	Waterfront cross-sections	181
6.7	Nominal depth and design depth of harbour bottom (R 36)	182
6.7.1	Nominal depth in seaports	182
6.7.2	Nominal depth of harbour bottom for inland ports	182
6.7.3	Design depth in front of quay wall	183
6.8	Strengthening waterfront structures for deepening harbour bottoms in seaports (R 200)	184
6.8.1	General	184
6.8.2	Design of strengthening measures	185
6.9	Embankments below waterfront wall superstructures behind closed sheet pile walls (R 68)	189
6.9.1	Embankment loads	189
6.9.2	Risk of silting-up behind sheet pile wall	190
6.10	Redesign of waterfront structures in inland ports (R 201)	190
6.10.1	General	190
6.10.2	Redesign options	190
6.10.3	Construction examples	191
6.11	Provision of quick-release hooks at berths for large vessels (R 70)	193
6.12	Layout, design and loads of access ladders (R 14)	194
6.12.1	Layout	194
6.12.2	Design	194
6.13	Layout and design of stairs in seaports (R 24)	197
6.13.1	Layout of stairs	197
6.13.2	Practical stair dimensions	198
6.13.3	Landings	198
6.13.4	Railings	198
6.13.5	Mooring equipment	198
6.13.6	Stairs in sheet pile structures	198
6.14	Equipment for waterfront structures in seaports with supply and disposal systems (R 173)	199
6.14.1	General	199
6.14.2	Water supply systems	199
6.14.3	Electricity supply systems	200
6.14.4	Other systems	201
6.14.5	Disposal systems	202
6.15	Fenders for large vessels (R 60)	202
6.15.1	General	202
6.15.2	The fendering principle	203
6.15.3	Design principles for fenders	204
6.15.4	Required energy absorption capacity	205
6.15.5	Types of fender system	211
6.15.6	Construction guidance	216

6.15.7	Chains	217
6.15.8	Guiding devices and edge protection	217
6.16	Fenders in inland ports (R 47)	219
6.17	Foundations to craneways on waterfront structures (R 120)	220
6.17.1	General	220
6.17.2	Design of foundations, tolerances	221
6.18	Fixing crane rails to concrete (R 85)	223
6.18.1	Supporting the crane rail on a continuous steel plate on a continuous concrete base	223
6.18.2	Bridge-type arrangement with rail supported centrally on bearing plates	223
6.18.3	Bridge-type arrangement with rail supported on chairs	227
6.18.4	Traversable craneways	227
6.18.5	Note on rail wear	230
6.18.6	Local bearing pressure	231
6.19	Connection of expansion joint seal in reinforced concrete bottom to loadbearing steel sheet pile wall (R 191)	231
6.20	Connecting steel sheet piling to a concrete structure (R 196)	231
6.21	Floating berths in seaports (R 206)	236
6.21.1	General	236
6.21.2	Design principles	236
6.21.3	Loading assumptions and design	237
7	Earthworks and dredging	238
7.1	Dredging in front of quay walls in seaports (R 80)	238
7.2	Dredging and hydraulic fill tolerances (R 139)	240
7.2.1	General	240
7.2.2	Dredging tolerances	240
7.3	Hydraulic filling of port areas for planned waterfront structures (R 81)	242
7.3.1	General	242
7.3.2	Hydraulic filling of port above the water table	245
7.3.3	Hydraulic filling of port areas below the water table	246
7.4	Backfilling of waterfront structures (R 73)	249
7.4.1	General	249
7.4.2	Backfilling in the dry	249
7.4.3	Backfilling underwater	250
7.4.4	Additional remarks	250
7.5	In situ density of hydraulically filled non-cohesive soils (R 175)	251
7.5.1	General	251
7.5.2	Empirical values for in situ density	251
7.5.3	In situ density required for port areas	252
7.5.4	Checking the in situ density	252
7.6	In situ density of dumped non-cohesive soils (R 178)	252
7.6.1	General	252

7.6.2	Influences on the achievable in situ density	253
7.7	Dredging underwater slopes (R 138)	254
7.7.1	General	254
7.7.2	Dredging underwater slopes in loose sand	254
7.7.3	Dredging plant	255
7.7.4	Execution of dredging work	255
7.8	Subsidence of non-cohesive soils (R 168).	257
7.9	Soil replacement along a line of piles for a waterfront structure (R 109)	258
7.9.1	General	258
7.9.2	Dredging	259
7.9.3	Quality and procurement of the fill sand	261
7.9.4	Cleaning the base of the excavation before filling with sand	262
7.9.5	Placing the sand fill	263
7.9.6	Checking the sand fill	264
7.10	Dynamic compaction of the soil (R 188)	264
7.11	Vertical drains to accelerate the consolidation of soft cohesive soils (R 93).	265
7.11.1	General	265
7.11.2	Applications	265
7.11.3	Design.	265
7.11.4	Design of plastic drains	267
7.11.5	Installation.	268
7.12	Consolidation of soft cohesive soils by preloading (R 179).	268
7.12.1	General	268
7.12.2	Applications	269
7.12.3	Bearing capacity of in situ soil	270
7.12.4	Fill material	270
7.12.5	Determining the depth of preload fill	270
7.12.6	Minimum extent of preload fill.	273
7.12.7	Soil improvement through vacuum consolidation with vertical drains	273
7.12.8	Execution of soil improvement through vacuum consolidation with vertical drains	274
7.12.9	Checking the consolidation	274
7.12.10	Secondary settlement	275
7.13	Improving the bearing capacity of soft cohesive soils with vertical elements (R 210)	275
7.13.1	General	275
7.13.2	Methods	275
7.13.3	Construction of pile-type loadbearing elements.	277
7.13.4	Design of geotextile-encased columns	278
7.13.5	Construction of geotextile-encased columns	279
8	Sheet piling structures	281
8.1	Materials and construction	281

8.1.1	Design and installation of timber sheet pile walls (R 22)	281
8.1.2	Design and installation of reinforced concrete sheet pile walls (R 21)	284
8.1.3	Design and installation of steel sheet pile walls (R 34)	287
8.1.4	Combined steel sheet piling (R 7)	288
8.1.5	Shear-resistant interlock connections for steel sheet piling (R 103)	292
8.1.6	Quality requirements for steels and dimensional tolerances for steel sheet piles (R 67)	296
8.1.7	Acceptance conditions for steel sheet piles and steel piles on site (R 98)	298
8.1.8	Corrosion of steel sheet piling, and countermeasures (R 35)	300
8.1.9	Danger of sand abrasion on sheet piling (R 23)	309
8.1.10	Shock blasting to assist the driving of steel sheet piles (R 183)	309
8.1.11	Driving steel sheet piles (R 118)	312
8.1.12	Driving combined steel sheet piling (R 104)	316
8.1.13	Monitoring during the installation of sheet piles, tolerances (R 105)	321
8.1.14	Noise control – low-noise driving (R 149)	325
8.1.15	Driving of steel sheet piles and steel piles at low temperatures (R 90)	330
8.1.16	Repairing interlock declutching on driven steel sheet piling (R 167)	331
8.1.17	Reinforced steel sheet piling (R 176)	334
8.1.18	Design of piling frames (R 140)	340
8.1.19	Design of welded joints in steel piles and steel sheet piles (R 99)	344
8.1.20	Cutting off the tops of driven steel sections for loadbearing welded connections (R 91)	347
8.1.21	Watertightness of steel sheet piling (R 117)	347
8.1.22	Waterfront structures in regions with mining subsidence (R 121)	350
8.1.23	Vibratory driving of U- and Z-section steel sheet piles (R 202)	353
8.1.24	Water-jetting to assist the driving of steel sheet piles (R 203)	357
8.1.25	Pressing of U- and Z-section steel sheet piles (R 212)	360
8.2	Design of sheet piling	361
8.2.1	General	361
8.2.2	Free-standing sheet piling structures (R 161)	366
8.2.3	Design of sheet piling structures with fixity in the ground and a single anchor (R 77)	367
8.2.4	Design of sheet pile walls with double anchors (R 134)	372
8.2.5	Applying the angle of earth pressure and the analysis in the vertical direction (R 4)	373
8.2.6	Taking account of unfavourable groundwater flows in the passive earth pressure zone (R 199)	386
8.2.7	Verifying the loadbearing capacity of the elements of sheet piling structures (R 20)	386
8.2.8	Selection of embedment depth for sheet piling (R 55)	390
8.2.9	Determining the embedment depth for sheet pile walls with full or partial fixity in the soil (R 56)	391
8.2.10	Steel sheet piling with staggered embedment depths (R 41)	394

8.2.11	Horizontal actions on steel sheet pile walls in the longitudinal direction of the quay (R 132)	397
8.2.12	Design of anchor walls fixed in the ground (R 152)	400
8.2.13	Staggered arrangement of anchor walls (R 42)	401
8.2.14	Steel sheet piling founded on bedrock (R 57)	401
8.2.15	Waterfront sheet piling in unconsolidated, soft cohesive soils, especially in connection with non-sway structures (R 43)	402
8.2.16	Design of single-anchor sheet piling structures in earthquake zones (R 125)	404
8.3	Calculation and design of cofferdams	405
8.3.1	Cellular cofferdams as excavation enclosures and waterfront structures (R 100)	405
8.3.2	Double-wall cofferdams as excavation enclosures and waterfront structures (R 101)	417
8.3.3	Narrow moles in sheet piling (R 162)	422
8.4	Walings, capping beams and anchor connections	424
8.4.1	Design of steel walings for sheet piling (R 29)	424
8.4.2	Verification of steel walings (R 30)	425
8.4.3	Sheet piling walings of reinforced concrete with driven steel anchor piles (R 59)	427
8.4.4	Steel capping beams for sheet piling waterfront structures (R 95)	431
8.4.5	Reinforced concrete capping beams for waterfront structures with steel sheet piling (R 129)	435
8.4.6	Steel nosings to protect reinforced concrete walls and capping beams on waterfront structures (R 94)	441
8.4.7	Auxiliary anchors at the top of steel sheet piling structures (R 133)	444
8.4.8	Screw threads for sheet piling anchors (R 184)	445
8.4.9	Sheet piling anchors in unconsolidated, soft cohesive soils (R 50)	447
8.4.10	Design of protruding quay wall corners with round steel tie rods (R 31)	450
8.4.11	Design and calculation of protruding quay wall corners with raking anchor piles (R 146)	453
8.4.12	High prestressing of high-strength steel anchors for waterfront structures (R 151)	457
8.4.13	Hinged connections between driven steel anchor piles and steel sheet piling structures (R 145)	458
8.5	Verification of stability for anchoring at the lower failure plane (R 10)	469
8.5.1	Stability at the lower failure plane for anchorages with anchor walls	469
8.5.2	Stability at the lower failure plane in unconsolidated, saturated cohesive soils	471
8.5.3	Stability at the lower failure plane with varying soil strata	471
8.5.4	Verification of stability at the lower failure for a quay wall fixed in the soil	472
8.5.5	Stability at the lower failure plane for an anchor wall fixed in the soil	473
8.5.6	Stability at the lower failure plane for anchors with anchor plates	473

8.5.7	Verification of safety against failure of anchoring soil	473
8.5.8	Stability at the lower failure plane for quay walls anchored with anchor piles or grouted anchors at one level	474
8.5.9	Stability at the lower failure plane for quay walls with anchors at more than one level	475
8.5.10	Safety against slope failure.	477
9	Tension piles and anchors (R 217)	478
9.1	General	478
9.2	Displacement piles.	478
9.2.1	Installation.	478
9.2.2	Types	479
9.2.3	Loadbearing capacity of displacement piles	480
9.3	Micropiles.	481
9.3.1	Installation.	481
9.3.2	Types	482
9.3.3	Loadbearing capacity of micropiles	482
9.4	Special piles	483
9.4.1	General	483
9.4.2	Prefabricated raking piles.	483
9.5	Anchors.	484
9.5.1	Construction	484
9.5.2	Types	484
9.5.3	Loadbearing capacity of anchors	485
10	Quay walls and superstructures in concrete	486
10.1	Design principles for quay walls and superstructures in concrete (R 17)	486
10.1.1	General principles	486
10.1.2	Edge protection	486
10.1.3	Facing	487
10.2	Design and construction of reinforced concrete components in waterfront structures (R 72)	487
10.2.1	Preliminary remarks.	487
10.2.2	Concrete	487
10.2.3	Construction joints.	488
10.2.4	Structures with large longitudinal dimensions	489
10.2.5	Crack width limitation	490
10.3	Formwork in areas affected by tides and waves (R 169)	491
10.4	Box caissons as waterfront structures in seaports (R 79)	491
10.4.1	General	491
10.4.2	Design.	492
10.4.3	Safety against sliding.	492

10.4.4	Construction details	493
10.4.5	Construction work	493
10.5	Compressed-air caissons as waterfront structures (R 87)	493
10.5.1	General	493
10.5.2	Verification	495
10.5.3	Safety against sliding	495
10.5.4	Construction details	495
10.5.5	Work on site	497
10.5.6	Frictional resistance during sinking	497
10.6	Design and construction of block-type quay walls (R 123)	498
10.6.1	Basic principles	498
10.6.2	Forces acting on a block wall	500
10.6.3	Design	501
10.7	Design of quay walls using open caissons (R 147)	503
10.7.1	General	503
10.7.2	Verification	504
10.7.3	Construction details	504
10.7.4	Work on site	506
10.7.5	Frictional resistance during sinking	506
10.7.6	Preparation of the subsoil	506
10.8	Design and construction of solid waterfront structures (e.g. blocks, box caissons, compressed-air caissons) in earthquake zones (R 126)	507
10.8.1	General	507
10.8.2	Active and passive earth pressures, excess water pressure, variable loads	507
10.8.3	Safety	507
10.8.4	Base of the wall	507
10.9	Use and design of bored cast-in-place piles (R 86)	507
10.9.1	General	507
10.9.2	Design	507
10.9.3	Construction of bored cast-in-place pile walls	509
10.9.4	Construction guidance	509
10.10	Use and design of diaphragm walls (R 144)	510
10.10.1	General	510
10.10.2	Verifying the stability of the open trench	512
10.10.3	Composition of the supporting slurry	512
10.10.4	Diaphragm wall construction	513
10.10.5	Concrete and reinforcement	513
10.10.6	Guidance for the design of diaphragm walls	514
10.11	Survey prior to repairing concrete components in hydraulic engineering structures (R 194)	515
10.11.1	General	515
10.11.2	Tests performed on the structure	516
10.11.3	Tests performed in the laboratory	517

10.11.4	Theoretical investigations	518
10.12	Repairing concrete components in hydraulic engineering structures (R 195)	518
10.12.1	General	518
10.12.2	Assessing the actual condition	519
10.12.3	Planning the repair works.	520
10.12.4	Execution of the repair works.	521
11	Pile bents and trestles	528
11.1	General	528
11.2	Calculating subsequently strengthened pile bents/trestles (R 45)	528
11.2.1	General	528
11.2.2	Loads	529
11.2.3	Calculation for cohesive substrata	530
11.2.4	Load from excess water pressure	530
11.3	Design of plane pile bents (R 78)	531
11.4	Design of spatial pile trestles (R 157)	534
11.4.1	Special structures designed as spatial pile trestles	535
11.4.2	Free-standing pile trestles.	535
11.4.3	Structural system and calculations	537
11.4.4	Construction guidance	537
11.5	Design of piled structures in earthquake zones (R 127)	539
11.5.1	General	539
11.5.2	Active and passive earth pressures, excess water pressure, variable loads	539
11.5.3	Resisting the horizontal inertial forces of the superstructure	539
12	Protection and stabilisation structures	541
12.1	Embankment stabilisation on inland waterways (R 211)	541
12.1.1	General	541
12.1.2	Loads on inland waterways	541
12.1.3	Construction of bank protection	542
12.1.4	Toe protection	545
12.1.5	Junctions	546
12.1.6	Design of revetments	547
12.2	Slopes in seaports and tidal inland ports (R 107)	547
12.2.1	General	547
12.2.2	Examples of impermeable revetments.	550
12.3	Use of geotextile filters in bank and bottom protection (R 189)	552
12.3.1	General	552
12.3.2	Design principles	552
12.3.3	Requirements.	553
12.3.4	Additional measures	553

12.3.5	General installation guidelines	554
12.4	Scour and protection against scour in front of waterfront structures (R 83)	555
12.4.1	General	555
12.4.2	Choosing a greater design depth (allowance for scouring)	556
12.4.3	Covering the bottom (scour protection)	557
12.4.4	Current velocity at revetment due to propeller wash	560
12.4.5	Designing bottom protection	564
12.5	Scour protection at piers and dolphins	566
12.6	Installation of mineral impervious linings underwater and their connection to waterfront structures (R 204)	567
12.6.1	Concept	567
12.6.2	Installation in dry conditions	567
12.6.3	Installation in wet conditions	567
12.6.4	Connections	568
12.7	Flood defence walls in seaports (R 165)	569
12.7.1	General	569
12.7.2	Critical water levels	569
12.7.3	Excess water pressure and unit weight of soil	570
12.7.4	Minimum embedment depths for flood defence walls	571
12.7.5	Special loads on flood defence walls	571
12.7.6	Guidance on designing flood defence walls in slopes	572
12.7.7	Constructional measures	572
12.7.8	Buried services in the region of flood defence walls	573
12.8	Dumped moles and breakwaters (R 137)	574
12.8.1	General	574
12.8.2	Stability analyses, settlement and subsidence, guidance on construction	574
12.8.3	Specifying the geometry of the structure	575
12.8.4	Designing the armour layer	580
12.8.5	Construction of breakwaters	582
12.8.6	Construction and use of plant	583
12.8.7	Settlement and subsidence	585
12.8.8	Invoicing for installed quantities	586
13	Dolphins (R 218)	587
13.1	General principles	587
13.1.1	Dolphins – purposes and types	587
13.1.2	Stiffness of the system	587
13.1.3	Loads on dolphins and design principles	587
13.1.4	Actions	590
13.1.5	Safety concept	592
13.2	Design of dolphins	592
13.2.1	Soil–structure interaction and the resulting design variables	592

13.2.2	Required energy absorption capacity of breasting dolphins	599
13.2.3	Other calculations	600
13.3	Construction and arrangement of dolphins (R 128)	601
13.3.1	Type of dolphin structure	601
13.3.2	Layout of dolphins	601
13.3.3	Equipment for dolphins	602
13.3.4	Advice for selecting materials	603
14	Inspection and monitoring of waterfront structures (R 193)	604
14.1	General	604
14.2	Documentation	606
14.3	Carrying out structural inspections	606
14.3.1	Structural check/Principle check	606
14.3.2	Structural monitoring/Intermediate inspection	607
14.3.3	Structural survey/Routine inspection	608
14.4	Inspection intervals	608
14.5	Maintenance management systems	609
Annex I Bibliography		610
I.1	Annual technical reports	610
I.2	Books and papers	611
I.3	Technical standards	623
Annex II Notation		626
II.1a	Latin lower-case letters	626
II.1b	Latin upper-case letters	627
II.1c	Greek letters	629
II.2	Subscripts and indexes	630
II.3	Abbreviations	631
II.4	Designations for water levels and wave heights	632
Annex III List of keywords		633