
Contents

<i>Preface</i>	ix
<i>Illustration credits</i>	xi
<i>Acknowledgements</i>	xiii
1 Introduction	1
<i>References</i>	4
2 Corrosion of steel in concrete	7
2.1 <i>The corrosion process</i>	8
2.2 <i>Black rust</i>	10
2.3 <i>Pits, stray current and bacterial corrosion</i>	10
2.4 <i>Electrochemistry, cells and half cells</i>	14
2.5 <i>Conclusions</i>	15
<i>References</i>	16
3 Causes and mechanisms of corrosion in concrete	17
3.1 <i>Carbonation</i>	17
3.2 <i>Chloride attack</i>	21
3.3 <i>Corrosion damage</i>	26
3.4 <i>Cracks, crack orientation and corrosion</i>	29
3.5 <i>The synergistic relationship between chloride and carbonation attack, chloride binding and release</i>	30
<i>References</i>	30
4 Condition evaluation	31
4.1 <i>Desk study</i>	33
4.2 <i>Preliminary survey</i>	33

4.3	<i>The detailed survey</i>	33
4.4	<i>Available techniques</i>	35
4.5	<i>Visual inspection</i>	36
4.6	<i>Delamination</i>	37
4.7	<i>Cover</i>	42
4.8	<i>Reference electrode (half cell) potential measurements</i>	44
4.9	<i>Carbonation depth measurement</i>	55
4.10	<i>Chloride determination</i>	57
4.11	<i>Resistivity measurement</i>	63
4.12	<i>Corrosion rate measurement</i>	68
4.13	<i>Permeability and absorption tests</i>	81
4.14	<i>Concrete characteristics: cement content, petrography, W/C ratio</i>	83
4.15	<i>Ground penetrating radar</i>	84
4.16	<i>Ultrasonic pulse velocity</i>	86
4.17	<i>Impact-echo</i>	89
4.18	<i>Radiography</i>	90
4.19	<i>Survey and assessment methodology</i>	93
4.20	<i>Special conditions – prestressing and coated rebars</i>	94
	<i>References</i>	96
5	Corrosion monitoring	103
5.1	<i>Regular surveys to monitor corrosion</i>	104
5.2	<i>Permanent corrosion monitoring systems</i>	104
5.3	<i>Remote monitoring systems and data management</i>	112
	<i>References</i>	112
6	Physical and chemical repair and rehabilitation techniques	115
6.1	<i>Concrete removal and surface preparation</i>	116
6.2	<i>Patches</i>	122
6.3	<i>Coatings, sealers, membranes and barriers</i>	125
6.4	<i>Encasement and overlays</i>	131
6.5	<i>Sprayed concrete</i>	132
6.6	<i>Corrosion inhibitors</i>	133
6.7	<i>Standards and guidance on physical and chemical repair</i>	138
	<i>References</i>	140

7 Electrochemical repair techniques	143
7.1 <i>Basic principles of electrochemical techniques</i>	143
7.2 <i>Cathodic protection principles</i>	144
7.3 <i>Galvanic anode systems</i>	149
7.4 <i>The components of an impressed current cathodic protection system</i>	156
7.5 <i>Cathodic protection system design</i>	177
7.6 <i>Control criteria</i>	182
7.7 <i>Standards and guidance documents for cathodic protection of steel in concrete</i>	185
7.8 <i>System installation</i>	188
7.9 <i>Cathodic protection of prestressed concrete</i>	193
7.10 <i>Cathodic protection of epoxy coated reinforcing steel</i>	194
7.11 <i>Cathodic protection of structures with ASR</i>	195
7.12 <i>Electrochemical chloride extraction</i>	195
7.13 <i>Realkalization</i>	204
7.14 <i>Standards and guidance for electrochemical chloride extraction and realkalization</i>	206
7.15 <i>Electro-osmosis</i>	207
7.16 <i>Comparison of techniques</i>	208
<i>References</i>	210
8 Rehabilitation methodology	215
8.1 <i>Technical differences between repair options</i>	216
8.2 <i>Repair costs</i>	216
8.3 <i>Carbonation options</i>	220
8.4 <i>Chloride options</i>	224
8.5 <i>Standards and guidance for selection of repairs</i>	229
8.6 <i>Training</i>	232
<i>References</i>	234
9 Modelling and calculating corrosion, deterioration and life cycle costing of reinforced concrete structures	237
9.1 <i>Activation time T_0 carbonation-induced corrosion</i>	237
9.2 <i>Chloride ingress rates (initiation)</i>	240
9.3 <i>Rate of depassivation (activation)</i>	243
9.4 <i>Activation time T_1</i>	243
9.5 <i>The Clear/Stratfull empirical calculation</i>	246
9.6 <i>Corrosion without spalling and high corrosion rates</i>	246

9.7	<i>Cracking and spalling rates, condition indexes and end of functional service life</i>	247
9.8	<i>Summary of methodology to determine service life</i>	248
9.9	<i>Diffusion models proposed in literature</i>	249
	<i>References</i>	251
10	Design for durability	255
10.1	<i>Cover, concrete and design</i>	255
10.2	<i>Fusion bonded epoxy coated rebars</i>	258
10.3	<i>Galvanized rebar</i>	264
10.4	<i>Penetrating sealers</i>	265
10.5	<i>Other corrosion resistant reinforcement</i>	265
10.6	<i>Waterproofing membranes</i>	265
10.7	<i>Stainless steel reinforcement</i>	267
10.8	<i>Corrosion inhibitors</i>	268
10.9	<i>Installing cathodic protection in new structures</i>	269
10.10	<i>Durable buildings</i>	270
10.11	<i>Conclusions</i>	272
	<i>References</i>	272
11	Sustainability and future developments	275
	<i>References</i>	278
	<i>Appendix: Sources of information on corrosion of steel in concrete</i>	279
	<i>Glossary and index</i>	283