



FUNDAMENTALS OF DURABLE REINFORCED CONCRETE

MARK G. RICHARDSON

Contents

<i>Preface</i>	xi
<i>Acknowledgements</i>	xii
1 Framework for durability by specification	1
<i>Context 1</i>	
<i>Key issues 2</i>	
<i>Historical review 3</i>	
<i>Specifying durable concrete: the options 11</i>	
<i>Durability and the next generation of standards 18</i>	
<i>Summary 18</i>	
2 Probabilistic approach to durability design	20
<i>Design life 20</i>	
<i>Structural design analogy 22</i>	
<i>Approach to design for durability 26</i>	
<i>Future research needs 33</i>	
<i>Application in practice 35</i>	
<i>Summary 37</i>	
3 Permeability and transport processes	38
<i>Pore structure and the hydration process 40</i>	
<i>Transport processes and rates 43</i>	
<i>Measurement of permeation properties 46</i>	
<i>Factors influencing the permeability of site concrete 49</i>	
4 Corrosion of reinforcement in concrete	51
<i>Nature of corrosion damage 51</i>	
<i>Electrochemical process 54</i>	
<i>Polarisation curves, the 'Evans Diagram' 60</i>	
<i>Passivity 61</i>	

	<i>Corrosion mechanism in carbonated concrete</i>	62
	<i>Corrosion mechanism in chloride-rich concrete</i>	63
	<i>Influences on corrosion activity</i>	65
	<i>Influence of cracking</i>	67
	<i>Modelling the rate of corrosion</i>	69
	<i>Monitoring corrosion activity</i>	71
	<i>Summary</i>	76
5	Carbonation	77
	<i>Carbonation and corrosion</i>	77
	<i>Chemistry of carbonation</i>	78
	<i>Detection of the carbonation front</i>	79
	<i>Primary factors influencing carbonation rate</i>	81
	<i>Mathematical modelling of the rate of carbonation</i>	85
	<i>Application of models to service life prediction</i>	94
	<i>Carbonation: exposure categories in EN 206-1</i>	97
	<i>Specification by performance</i>	99
	<i>Summary</i>	100
6	Chloride ingress	101
	<i>Chloride ingress and corrosion</i>	101
	<i>Detection and expression of chloride levels</i>	105
	<i>Critical chloride level for corrosion</i>	107
	<i>Primary factors influencing chloride ingress</i>	111
	<i>Mathematical modelling of chloride ingress</i>	114
	<i>Application of models to service life prediction</i>	121
	<i>Chlorides: limitations and exposure categories in EN 206-1</i>	124
	<i>Specification by performance</i>	129
	<i>Summary</i>	132
7	Alkali-silica reaction	133
	<i>Background</i>	133
	<i>Manifestation of the problem</i>	135
	<i>Mechanism of expansion and reaction</i>	139
	<i>Primary factors influencing the reaction</i>	141
	<i>Other factors influencing ASR occurrence</i>	145
	<i>Modelling and service life prediction</i>	148
	<i>Specifications to minimise the risk of ASR</i>	149
	<i>Summary</i>	159

8	Freeze/thaw effects	160
	<i>Background</i>	160
	<i>Primary factors of influence</i>	162
	<i>Air entrainment</i>	165
	<i>Developments in specification and design practice</i>	166
	<i>Freeze/thaw attack: exposure categories in EN 206-1</i>	170
	<i>Developments in testing</i>	173
	<i>Specification by performance</i>	176
	<i>Summary</i>	177
9	Chemical attack: sulfates	179
	<i>Introduction</i>	179
	<i>Physico-chemical aspects</i>	180
	<i>Factors influencing sulfate attack</i>	184
	<i>Approaches in specification and design practice</i>	188
	<i>Sulfate attack: exposure categories in EN 206-1</i>	190
	<i>Developments in testing and specification by performance</i>	192
	<i>Summary</i>	193
10	Chemical attack: acid and seawater attack	194
	<i>Introduction</i>	194
	<i>Physico-chemical aspects</i>	196
	<i>Factors influencing attack</i>	199
	<i>Mathematical modelling of acid attack</i>	201
	<i>Approaches in specification and design practice</i>	203
	<i>Acid and seawater attack: exposure categories in EN 206-1</i>	204
	<i>Specification by performance</i>	206
	<i>Summary</i>	206
11	Cracking in reinforced concrete structures	208
	<i>Introduction</i>	208
	<i>Mechanism of cracking</i>	209
	<i>Chronological aspects of cracking</i>	212
	<i>Cracking and the design phase</i>	213
	<i>Cracking during the construction phase</i>	220
	<i>Cracking during the service phase</i>	225
	<i>Cracking and corrosion of reinforcement</i>	229
	<i>Summary</i>	230

x *Contents*

12	Abrasion, erosion and cavitation	232
	<i>Surface deterioration</i>	232
	<i>Abrasion</i>	233
	<i>Erosion</i>	235
	<i>Cavitation</i>	235
13	Weathering and efflorescence	237
	<i>Weathering</i>	237
	<i>Efflorescence</i>	238
	<i>References</i>	241
	<i>Index</i>	255