

Table of contents

- **Preface** (p. xiii)
- **The Author** (p. xv)
- **Chapter 1 Introduction** (p. 1)
- **Reference** (p. 3)
- **Chapter 2 Corrosion of Steel in Concrete** (p. 5)
 - **2.1 Introduction** (p. 5)
 - **2.2 The Corrosion Process** (p. 7)
 - **2.3 Black Corrosion** (p. 9)
 - **2.4 Pit Formation** (p. 9)
 - **2.5 Bacterial Corrosion** (p. 10)
 - **2.6 Corrosion Rate** (p. 10)
 - **2.7 Summary** (p. 13)
- **References** (p. 13)
- **Chapter 3 Causes of Corrosion and Concrete Deterioration** (p. 15)
 - **3.1 Introduction** (p. 15)
 - **3.2 Carbonation** (p. 16)
 - **3.3 Spread of Carbonation inside Concrete** (p. 19)
 - **3.3.1 Parrott's Determination of Carbonation Rates from Permeability** (p. 21)
 - **3.4 Chloride Attack** (p. 21)
 - **3.5 Chloride Movement inside Concrete** (p. 22)
 - **3.6 Corrosion Rates** (p. 23)
 - **3.6.1 Statistical Analysis for Initiation of Corrosion and Corrosion Rate** (p. 23)
 - **3.7 Effect of Age on Concrete Strength** (p. 24)
 - **3.7.1 Statistical Analysis of Longtime Concrete Strength** (p. 26)
 - **3.7.2 Code Recommendations** (p. 26)
 - **3.7.3 Available Statistical Parameters for Concrete Strength Considering Age** (p. 27)
 - **3.8 Corrosion's Effect on Spalling of Concrete Cover** (p. 27)
- **References** (p. 32)
- **Chapter 4 Assessment Methods for Reinforced Concrete Structures** (p. 33)
 - **4.1 Introduction** (p. 33)
 - **4.2 Preliminary Inspection** (p. 34)
 - **4.3 Detailed Inspection** (p. 34)
 - **4.4 Methods of Structure Assessment** (p. 35)
 - **4.4.1 Visual Inspection** (p. 36)
 - **4.4.1.1 Plastic Shrinkage** (p. 36)
 - **4.4.1.2 Settlement** (p. 37)
 - **4.4.1.3 Shrinkage from Drying** (p. 37)
 - **4.4.1.4 Thermal Stresses** (p. 38)
 - **4.4.1.5 Chemical Reaction** (p. 39)
 - **4.4.2 Concrete Test Data** (p. 44)
 - **4.4.2.1 Core Test** (p. 44)
 - **4.4.2.2 Rebound Hammer** (p. 48)

- **4.4.2.3 Ultrasonic Pulse Velocity** (p. 51)
- **4.4.2.4 Load Test for Concrete Members** (p. 56)
- **4.4.2.5 Comparison between Different Tests** (p. 59)
- **4.4.3 Sources of Concrete Failure** (p. 60)
- **4.4.4 Example for Structure Evaluation** (p. 61)
- **4.4.5 Example for Structure Assessment** (p. 63)
- **4.5 Test Methods for Corroded Steel in Concrete** (p. 65)
- **4.5.1 Manual Method** (p. 65)
- **4.5.2 Concrete Cover Measurements** (p. 67)
- **4.5.3 Half-Cell Potential Measurements** (p. 69)
- **4.5.4 Electrical Resistivity Measurement** (p. 71)
- **4.5.5 Measurement of Carbonation Depth** (p. 74)
- **4.5.6 Chloride Tests** (p. 74)
- **4.6 Building Assessment** (p. 75)
- **References** (p. 76)
- **Chapter 5 Codes and Specification Guides** (p. 79)
- **5.1 Introduction** (p. 79)
- **5.2 Allowable Chloride Content in Concrete** (p. 80)
- **5.3 Concrete Cover Specifications** (p. 81)
- **5.3.1 British Standards** (p. 82)
- **5.3.2 American Codes** (p. 82)
- **5.3.3 European Code** (p. 83)
- **5.3.4 Specifications for Structures Exposed to Very Severe Conditions** (p. 85)
- **5.3.5 Egyptian Code** (p. 85)
- **5.3.6 Executing Concrete Cover** (p. 87)
- **5.4 Maximum Crack Width** (p. 91)
- **5.4.1 Recommended Reinforcement Details of Crack Control** (p. 92)
- **5.5 Design Precautions in Cases of Carbonation** (p. 93)
- **5.6 Design Precautions for Chloride Effects** (p. 95)
- **5.6.1 Effect of the Diffusion Factor on Chloride Permeability** (p. 97)
- **5.6.2 Effect of Chloride Concentration on Surface** (p. 98)
- **5.6.3 Effective Chloride Concentration** (p. 99)
- **5.6.4 Calculating Structure Lifetime** (p. 99)
- **5.6.5 General Design Considerations** (p. 101)
- **References** (p. 102)
- **Chapter 6 Controlling Corrosion in Steel Bars** (p. 105)
- **6.1 Introduction** (p. 105)
- **6.2 Carbonation Process Control** (p. 106)
- **6.2.1 Effect of Environmental Conditions** (p. 106)
- **6.2.2 Components of Concrete Mix** (p. 109)
- **6.2.3 Curing** (p. 110)
- **6.3 Chloride Control** (p. 112)
- **6.3.1 Weather Factors Affecting Corrosion** (p. 112)
- **6.3.2 Composition of Concrete Mix** (p. 113)
- **6.3.3 Curing for Chloride Attack** (p. 114)

- **6.3.4 Execution of Curing** (p. 116)
- **6.3.4.1 The Curing Process in ACI** (p. 119)
- **6.3.4.2 British Standard for Curing** (p. 120)
- **6.4 Protecting Special Structures** (p. 121)
- **References** (p. 122)
- **Chapter 7 Methods for Protecting Steel Reinforcements** (p. 123)
- **7.1 Introduction** (p. 123)
- **7.2 Corrosion Inhibitors** (p. 124)
- **7.2.1 Anodic Inhibitors** (p. 124)
- **7.2.2 Cathodic Inhibitors** (p. 125)
- **7.3 Epoxy Coating of Steel Reinforcement** (p. 126)
- **7.4 Galvanized Steel Bars** (p. 127)
- **7.5 Stainless Steel** (p. 129)
- **7.6 Fiber Reinforcement Bars** (p. 130)
- **7.7 Protecting the Concrete Surface** (p. 131)
- **7.7.1 Sealers and Membranes** (p. 132)
- **7.7.1.1 Coating and Sealing** (p. 132)
- **7.7.1.2 Pore Lining** (p. 133)
- **7.7.1.3 Pore Blocking** (p. 133)
- **7.7.2 Cathodic Protection by Surface Painting** (p. 134)
- **7.8 Cathodic Protection System** (p. 135)
- **7.8.1 Cathodic Protection** (p. 135)
- **7.8.2 Cathodic Protection Components and Design Consideration** (p. 137)
- **7.8.2.1 Source of Impressed Current** (p. 138)
- **7.8.2.2 Anode System** (p. 138)
- **7.8.2.3 Conductive Layer** (p. 140)
- **7.8.2.4 Precautions in Designing the Anode** (p. 140)
- **7.8.2.5 Follow-Up Precaution** (p. 142)
- **7.8.3 Comparison between Cathodic Protection and Other Types of Protection** (p. 142)
- **7.8.4 Cathodic Protection for Prestressed Concrete** (p. 143)
- **7.8.5 Bond Strength in Cathodic Protection** (p. 144)
- **7.9 Concrete with Silica Fume** (p. 146)
- **References** (p. 146)
- **Chapter 8 Repair of Reinforced Concrete Structures** (p. 149)
- **8.1 Introduction** (p. 149)
- **8.2 Main Steps to Executing Repair** (p. 150)
- **8.2.1 Structure Strengthening** (p. 150)
- **8.2.2 Removing Concrete Cracks** (p. 151)
- **8.2.2.1 Manual Method** (p. 152)
- **8.2.2.2 Pneumatic Hammer Methods** (p. 152)
- **8.2.3 Water Jet** (p. 153)
- **8.2.4 Grinding Machine** (p. 155)
- **8.3 Clean Concrete Surfaces and Steel Reinforcements** (p. 155)
- **8.3.1 Concrete** (p. 155)
- **8.3.2 Clean Steel Reinforcement Bars** (p. 156)

- **8.4 New Patch Concrete** (p. 160)
- **8.4.1 Polymer Mortar** (p. 160)
- **8.4.2 Cement Mortar** (p. 161)
- **8.5 Execution Methods** (p. 161)
- **8.5.1 Manual Method** (p. 161)
- **8.5.2 Grouted Preplaced Aggregate** (p. 162)
- **8.5.3 Shotcrete** (p. 163)
- **8.6 Repair Steps** (p. 165)
- **8.7 New Methods for Strengthening Concrete Structures** (p. 165)
- **8.8 Using Steel Sections** (p. 166)
- **8.9 Fiber-Reinforced Polymer (FRP)** (p. 169)
- **8.9.1 CFRP** (p. 170)
- **8.9.2 Application On-site** (p. 171)
- **8.10 General Precautions** (p. 172)
- **References** (p. 173)
- **Chapter 9 Risk-Based Maintenance Strategy** (p. 175)
- **9.1 Introduction** (p. 175)
- **9.2 Basic Rules of Cost Calculation** (p. 176)
- **9.2.1 Present Value Method** (p. 176)
- **9.2.2 Repair Time** (p. 176)
- **9.2.3 Capacity Loss in Reinforced Concrete Sections** (p. 178)
- **9.3 Example** (p. 180)
- **9.3.1 Required Time to Start of Corrosion** (p. 181)
- **9.3.2 Time Required to Start of Deterioration** (p. 182)
- **9.3.3 Cost Analysis for Different Protection Methods** (p. 183)
- **9.4 Repair and Inspection Strategy and Optimization** (p. 185)
- **9.4.1 Repair** (p. 186)
- **9.4.2 Expected Total Cost** (p. 186)
- **9.4.3 Optimization Strategy** (p. 187)
- **9.5 Maintenance Plan** (p. 190)
- **9.5.1 Assessment Process** (p. 190)
- **9.5.2 Risk-Based Inspection Maintenance Plan** (p. 193)
- **References** (p. 195)
- **Index** (p. 197)