Contents

About the Authors *xiii*

1	Introduction 1
1.1	General 1
1.2	By Way of an Introduction: A Real Conversation About Anchors in a
	Private Situation 1
1.3	Anchor Technology for Professionals 4
2	European Regulations 9
2.1	General 9
2.2	European Technical Assessment (ETA) 9
2.3	CE Marking 9
2.4	The Most Important Regulations Referred to in this Book 11
2.4.1	European and International Standards (DIN EN, ISO) 11
2.4.2	Laws, Directives, Technical Rules 12
2.4.3	European Technical Approval Guidelines (ETAG), European Assessment
	Documents (EAD) and Technical Reports (TR) 12
2.4.4	European 'Approvals' (ETAs) 13
2.4.5	Test Reports 15
3	Base Material - In What Material Do I Want To Fasten My
	Anchors? 17
3.1	General 17
3.2	Identifying the Base Material on the Construction Site 17
3.2.1	Identifying the Base Material by Means of Construction Documents 18
3.2.1.1	Concrete 18
3.2.1.2	Masonry 19
3.2.2	Identifying the Base Material Without Construction Documents 19
3.2.2.1	Drilling a Test Hole 19
3.2.2.2	Options for Determining the Concrete Compressive Strength 23

Contents	
4	Base Materials in Detail 25
4.1	Concrete 25
4.1.1	General 25
4.1.2	Cracked (Reinforced) Concrete 25
4.1.3	Uncracked Concrete 29
4.1.4	Types of Concrete 30
4.1.4.1	General 30
4.1.4.2	Normal-weight Concrete 30
4.1.4.3	Lightweight Concrete 30
4.1.5	Compressive Strength Classes 32
4.1.5.1	Normal-weight and Heavyweight Concrete 32
4.1.5.2	Lightweight Concrete 35
4.2	Masonry 36
4.2.1	General 36
4.2.1.1	Masonry Units 36
4.2.1.2	Joints With and Without Mortar (Filled and Unfilled Joints) 36
4.2.2	Solid and Vertically Perforated Clay Bricks 37
4.2.3	Solid and Perforated Calcium Silicate Units 38
4.2.4	Solid and Hollow Lightweight Concrete Blocks 38
4.2.5	Aerated Concrete Blocks 40
4.2.6	Autoclaved Aerated Concrete: Wall, Floor and Roof Panels 40
4.2.7	Solid and Hollow Masonry Units Made From Normal-weight
	Concrete 42
4.2.8	Natural Stone 43
4.2.9	Base Materials Subsequently Insulated 44
5	Environment – Which External Influences Affect My
	Fastenings? 47
5.1	General 47
5.2	Temperature 48
5.3	Freezing Temperatures 50
5.4	Fire 51
5.5	Corrosion 52
5.5.1	Advice in the Approvals for Anchors 52
5.5.2	Advice for Anchoring Fastenings in Concrete According to EN
	1992-4 53
5.5.2.1	General 53
5.5.2.2	Defining a Dry Interior 54
5.5.2.3	Moisture 54
5.5.2.4	Chlorides and Other Aggressive Agents 54
5.5.3	Additional Helpful Information 56

6 Member Dimensions - Where Can I Install My Anchor? 59

Definitions of Important Terms and Dimensions in Anchor Technology 59

6.2	(Minimum) Member Thickness 61
6.2.1	Concrete 62
6.2.2	Masonry 62
6.3	Edge Distance c 63
6.3.1	Concrete 63
6.3.1.1	Minimum Edge Distance c_{\min} 63
6.3.1.2	Characteristic Edge Distance c_{cr} 64
6.3.2	Masonry 65
6.4	Spacing s 67
6.4.1	Concrete 67
6.4.1.1	Minimum Spacing s _{min} 67
6.4.1.2	Characteristic Spacing s_{cr} 68
6.4.2	Masonry 69
6.5	Regulations for Approved Plastic Anchors 71
7	Fixtures and Anchor Plates – What Do I Want to Fasten? 73
7.1	General 73
7.2	The Theory Behind Fixtures and Anchor Plates 74
7.3	The Support of the Fixture 75
7.3.1	General 75
7.3.2	Fixture with Statically Determinate Supports - Single Fastening 76
7.3.3	Fixture with Statically Indeterminate Supports - Multiple
	Fastenings 78
7.3.3.1	General 78
7.3.3.2	Distinguishing Between Structural and Non-structural Systems 79
7.3.3.3	Stiffness of the Fixture 80
7.3.3.4	Loads Acting on Multiple Fastenings 81
7.3.3.5	Limiting the Loads Acting per Fixing Point 82
7.3.3.6	Examples of Anchor Types Approved as Multiple Fasteners for
	Non-structural Systems 83
7.3.4	Summary With One Example 84
7.4	Clearance Holes in Fixtures 85
7.5	Types of Installation 87
7.5.1	General 87
7.5.2	Pre-positioned Installation 88
7.5.3	In-place Installation 88
7.6	Hole Patterns in Fixtures (Arrangement of Fastenings) 90
7.7	Fixtures and Anchor Plates in Practice 92
8	Actions - Which Loads Act on My Fastening? 95
8.1	General 95
8.2	Loading Directions (Nature of the Loading) 95
8.3	Action Effects (Types of Load) 96
8.4	Design is the Job of the Planning Team! 98
8.5	An Example to Illustrate Action Effects 99

viii	Contents	
	8.5.1	General 99
	8.5.2	Structural System 99
	8.5.3	Self-weight – Dead Load 101
	8.5.4	Imposed Loads 102
	8.5.5	Actions on the Anchors Due to Dead and Imposed Loads 102
	8.5.6	Dynamic Loads 103
	8.5.6.1	General 103
	8.5.6.2	The Pull-up Bar Example 104
	8.5.6.3	Dynamic Loads 104
	8.5.7	Summary 105
	9	Anchor Systems 107
	9.1	Introduction 107
	9.2	Anchor Systems for Anchorages in Concrete 107
	9.2.1	Metal Anchors 107
	9.2.1.1	Bolt Anchors 107
	9.2.1.2	Sleeve Anchors 109
	9.2.1.3	Drop-in Anchors 110
	9.2.1.4	Concrete Screws 114
	9.2.2	Bonded Anchors 117
	9.2.2.1	General 117
	9.2.2.2	Bonded Expansion Anchors for Use in Cracked Concrete 119
	9.2.2.3	Injection Systems 123
	9.2.2.4	Post-installed Rebar Connections 127
	9.2.2.5	Capsule Systems 128
	9.3	Anchor Systems for Anchorages in Concrete and Masonry – Plastic
	0.4	Anchors 129 Anchor Systems for Anchomogos in Masonny Unicetics Systems 124
	9.4	Anchor Systems for Anchorages in Masonry – Injection Systems 134
	10	Design 137
	11	Installation 139
	11.1	Installation Technicians - Qualified Personnel 139
	11.2	Drill Bits - Drilling - Cleaning Out Drilled Holes 139
	11.2.1	General 139
	11.2.2	Position of the Hole 140
	11.2.3	Drilling Methods 142
	11.2.3.1	Drilling with Rotary and Hammer Action 142
	11.2.3.2	C
	11.2.3.3	
	11.2.4	Cleaning the Drilled Hole 144
	11.2.4.1	General 144
	11.2.4.2	Cleaning Holes for Metal and Plastic Anchors 144
	11.2.4.3	Cleaning Holes for Injection and Cartridge Systems 145
	11.2.4.4	Vacuum Drill Bits for Dust Extraction 146

11.2.5	Aborted Holes 148
11.3	Temperature – Processing Time – Curing Time 149
12	Typical Mistakes and What We Can Do Differently or Better 151
12.1	General 151
12.2	Environment – Corrosion 151
12.3	Member Dimensions – Edge Distances and Spacings 153
12.4	Anchor Systems 159
12.5	Installation of Anchors 162
13	Summary – How Do I Solve My Fastening Task? 165
14	Determining the Resistances of Plastic Anchors and Metal Injection Anchors by Means of Job Site Tests 167
14.1	Introduction 167
14.2	Principles for Job Site Tests Involving Masonry Base Materials 169
14.2.1	Anchor Systems 169
14.2.2	European Technical Assessments for Plastic Anchors 170
14.2.3	European Technical Assessments for Metal Injection Anchors for
	Anchorages in Masonry 171
14.2.4	The Systematic Approach Behind this Part of this Book 171
14.3	Responsibilities 172
14.3.1	General 172
14.3.2	Competent Planner 173
14.3.3	Test Supervisor 174
14.3.4	Appropriately Trained Personnel 174
14.4	Technical Rule 'Execution and Evaluation of Job Site Tests of Plastic Anchors for Use in Concrete and Masonry with ETA' 175
14.4.1	Classification/General 175
14.4.2	Field of Application for Plastic Anchors 175
14.4.2.1	General 175
14.4.2.2	Base Material Groups (Masonry Groups) 176
14.4.2.3	
14.4.2.4	
14.4.2.5	Working 'Within the Scope of the ETA' 179
14.4.3	Tests for Plastic Anchors 179
14.4.3.1	General 179
14.4.3.2	Test to Failure 179
14.4.3.3	Proof Load Tests 180
14.4.4	Test Report 182
14.5	Practical Example 1: Tension Tests on Plastic Anchors (Tests to
	Failure) – Fastening of a Façade Support Structure 182
14.5.1	Introduction 182
14.5.2	Carrying Out and Recording Job Site Tests 185

14.5.2.1	General Information About the Construction Project 185
14.5.2.2	Location of Tests 185
14.5.2.3	Testing Apparatus 188
14.5.2.4	Nature of Constructional Item to be Fastened 193
14.5.2.5	Base Material 193
14.5.2.6	Name of Product 197
14.5.2.7	Installation 198
14.5.2.8	Test Results 201
14.5.3	Interim Conclusion: Division of Labour 202
14.5.4	Evaluation of Tension Tests (Tests to Failure) 204
14.5.4.1	Principles for Tension Tests 204
14.5.4.2	Determining the Characteristic Resistance with at Least Five Tests 204
14.5.4.3	Determining the Characteristic Resistance with the Simplified
	Method 205
14.5.4.4	Taking Joints into Account 208
14.5.4.5	Design Value of Resistance 210
14.5.5	Remarks and Advice 210
14.5.6	Signatures 210
14.6	Technical Rule 'Execution and Evaluation of Job Site Tests of Injection
	Anchor Systems for Use in Masonry with ETA' 211
14.6.1	Classification/General 211
14.6.2	Applications for Injection Anchors 212
14.6.2.1	General 212
14.6.2.2	Masonry Groups 212
14.6.2.3	Temperature Ranges 214
14.6.2.4	Conditions During Installation and Usage 215
14.6.2.5	Conditions for Spacing and Edge Distances 216
14.6.2.6	Acting 'Within the Scope of the ETA' 216
14.6.3	Tests 216
14.6.3.1	General 216
14.6.3.2	Tests to Failure 218
14.6.3.3	Proof Load Tests 219
14.6.3.4	Acceptance Tests 221
14.6.4	Test Report 223
14.7	Practical Example 2: Tension Tests for Injection Anchors (Tests to
	Failure) - Fastening a Balustrade for a French Balcony 224
14.7.1	Introduction 224
14.7.2	Execution of Job Site Tests and Associated Documentation 225
14.7.2.1	General Information About the Construction Project 225
14.7.2.2	Location of Tests 225
14.7.2.3	Testing Apparatus 225
14.7.2.4	Nature of Constructional Item to be Fastened 226
14.7.2.5	Base Material 226
14.7.2.6	Name of Product 228
14.7.2.7	Installation 228

14.7.2.8	Test Results 228
14.7.3	Interim Conclusion: Division of Labour 230
14.7.4	Evaluation of the Test Results 231
14.7.4.1	Principles for Tension Tests 231
14.7.4.2	Determining the Characteristic Resistance by Way of Fractiles 232
14.7.4.3	Determining the Characteristic Resistance with a Simplified
	Method 235
14.7.4.4	Taking Joints into Account 235
14.7.4.5	Design Value of Resistance 235
14.8	Summary 235
	References for Chapter 14 236
Appendi	x A Execution and Evaluation of Job Site Tests of Plastic Anchors for
	Use in Concrete and Masonry with ETA in Accordance with EAD
	330284-00-0604 or ETAG 020 <i>239</i>
A.1	Field of Application 239
A.1.1	General 239
A.1.2	Terminology 240
A.1.3	Conditions of Application 241
A.1.4	Symbols 242
A.2	Tests 243
A.2.1	Test Preparation 243
A.2.2	Test Procedure 244
A.2.3	Test Report 246
A.3	Evaluation of the Test Results 248
A.3.1	General 248
A.3.2	Tests Until Failure (Shear Tests on the Edge and Tension Tests) 248
A.3.3	Proof-Load Tests (Shear Tests on the Edge) 250
A.4	Information for Design 251
A.4.1	Characteristic Resistance 251
A.4.2	Spacing and Edge Distances 252
A.4.3	Partial Factor 252
A.4.4	Influence of Joints 252
	References 252
A.5	Annex A: Categories of Comparable Hollow and Perforated Bricks and
	Blocks 253
A.5.1	Instructions for Determining the Reference Unit 253
A.5.2	Description of Categories C1 to C7 (as follows) 254
Appendia	x B Execution and Evaluation of Job Site Tests of Injection Anchor

Systems for Use in Masonry with ETA in Accordance with EAD 330076-00-0604 or ETAG 029 *261*

- B.1 Field of Application 261
- B.1.1 Generales 261
- B.1.2 Terminology 262

xii	Contents	
i		

B.1.3	Conditions of Application 263
B.1.4	Symbols 264
B.2	Tests 266
B.2.1	Test Preparation 266
B.2.2	Test Procedure 267
B.2.3	Test Report 269
B.3	Evaluation of the Test Results 271
B.3.1	General 271
B.3.2	Tests Until Failure (Shear Tests on the Edge and Tension Tests) 272
B.3.3	Proof-Load Tests (Shear Tests on the Edge and Tension Tests) 273
B.3.4	Acceptance Tests (Tension Tests) 274
B.4	Information for Design 275
B.4.1	Characteristic Resistance 275
B.4.2	Spacing and Edge Distances 276
B.4.3	Partial Factor 277
B.4.4	Pulling Out or Pushing Out of One Brick 277
B.4.5	Influence of Joints 277
	References 278
B.5	Annex A: Categories of Comparable Hollow and Perforated Bricks and
	Blocks 279
B.5.1	Instructions for Determining the Reference Unit 279
B.5.2	Description of Categories C1 to C7 (as follows) 280