Contents

Foreword i
Editorial note i
Preface 1
1. RC jacketing 2
1.1 Foreword 2
1.2 Basics 3
1.2.1 When to adopt this method? 3
1.2.2 Materials 3
1.2.3 Techniques 4
1.2.4 Equipment 5
1.3 Stakeholders' roles and qualifications 6
1.3.1 Owner 6
1.3.2 Designer 6
1.3.3 Contractor 6
1.3.4 User 6
1.4 Design 6
1.4.1 Assessment of present conditions (existing concrete surface) 6
1.4.2 Design assumptions 7
1.4.3 Design procedure 8
1.4.4 Codes and other relevant references 9
1.5 Detailing 10
1.6 Execution 10
1.6.1 Preparatory works 10
1.6.2 Execution procedure 11
1.7 Quality control and monitoring 13
1.8 Case study 13
1.8.1 Description of the structure 13
1.8.2 Inspection Highlights 14
1.8.3 Description of the intervention methodology 17
1.8.4 Execution 18
1.8.5 Monitoring 20

2. FRP jacketing 22
2.1 Foreword 22
2.2 Basics 22
2.2.1 When to use this method 22
2.2.2 Materials 23
2.2.3 FRP jacketing Systems 26
2.3 Techniques 29
2.3.1 Basic FRP technique 29
2.3.2 Automated wrapping 29
2.3.3 Textile-reinforced mortar techniques (TRM) and Fabric Reinforced Cementitious Mortar (FRCM) 30
2.3.4 Prestressed jacketing 30
2.4 Personnel and equipment 31
2.4.1 Personnel 31
2.4.2 Equipment 31
2.5 Stakeholders' roles and qualifications 32
2.5.1 Owner 32
2.5.2 Designer 33
2.5.3 Contractor 33
2.6 Design 33
2.6.1 Assessment of existing conditions 33
2.6.2 Codes and standards and other relevant references 34
2.6.3 Design procedure 34
2.7 Quality control 35
2.7.1 Quality control of materials 35
2.7.2 Quality control before intervention 36
2.7.3 Quality control of FRP Durability 36
2.7.4 Quality control during intervention 37
2.7.5 Quality control after intervention 37
2.8 Monitoring and maintenance 38
2.8.1 Monitoring 38
2.8.2 Maintenance 38
2.9 References 39

2.10 Case study 1 40
2.10.1 Description of the structure 40
2.10.2 Description of the intervention project 40
2.10.3 Description of the strengthening procedure 40
2.11 Case study 2 43
2.11.1 Description of the structure 43
2.11.2 Bridge Capacity assessment 45
2.11.3 Rehabilitation Intervention by using innovative materials 45
3. Steel jacketing 49
3.1 Foreword 49
3.2 Basics – Technique description 50
3.2.1 When to adopt this method 50
3.2.2 Techniques and materials 51
3.2.3 Equipment 54
3.3 Stakeholders' roles and qualifications 54
3.3.1 Owner 54
3.3.2 Designer 55
3.3.3 Contractor 55
3.3.4 User 55
3.4 Design 56
3.4.1 Assessment of existing conditions 56
3.4.2 Service life and reliability requirements 56
3.4.3 Codes and standards and other relevant references 56
3.4.4 Design assumptions 58
3.4.5 Design procedure 58
3.4.6 Supporting documents 65
3.5 Execution 66
3.5.1 Preparatory works 66
3.5.2 Execution procedure 66
3.5.3 Finishing 68
3.6 Quality control 68
3.6.1 Quality control of materials before intervention 68
3.6.2 Quality control during intervention 68
3.6.3 Quality control after intervention 69
3.7 Monitoring and maintenance 69
3.7.1 Monitoring 69
3.7.2 Maintenance 69
3.7.3 Post-intervention documentation 69

3.8 Case study 1 70
3.8.1 Introduction 70
3.8.2 Description of the structure 70
3.8.3 Inspection highlights 72
3.8.4 Description of the intervention project 73
3.8.5 Seismic retrofit 74
3.8.6 Calculations for steel jacketing of a column 75
3.8.7 Description of the steel jacketing intervention works 82
3.8.8 References 83
3.9 Case study 2 84
3.9.1 Introduction 84
3.9.2 Description of the structure 85
3.9.3 Inspection highlights 86
3.9.4 Results obtained 87
3.9.5 Description of the intervention project 89
3.9.6 Description of the intervention works 90
3.9.7 Description of maintenance operations 92
4. Internally applied steel reinforcement 94
4.1 Foreword 94
4.2 Basics 94
4.2.1 When to adopt this method 94
4.2.2 Materials and systems 94
4.2.3 Techniques 95
4.2.4 Equipment 96
4.3 Stakeholders' roles and qualifications 97
4.3.1 Owner 97
4.3.2 Designer 97
4.3.3 Contractor 98
4.3.4 User 98
4.4 Design 98
4.4.1 Assessment of existing conditions 98
4.4.2 Service life 98
4.4.3 Reliability requirements 99
4.4.4 Codes and standards and other releveant references 99
4.4.5 Design assumptions 99
4.4.6 Design procedures 99
4.4.7 Supporting documents 101

4.5 Execution 101
4.5.1 Preparatory works 101
4.5.2 System trials 102
4.5.3 Execution procedure 102
4.6 Quality control 102
4.6.1 Quality control of materials 102
4.6.2 Quality control before intervention 102
4.6.3 Quality control during intervention 102
4.6.4 Quality control after intervention 103
4.7 Monitoring and maintenance 103
4.8 Case study 103
4.8.1 Description of the structure 103
4.8.2 Inspection highlights 103
4.8.3 Description of the intervention project 103
4.8.4 Description of the intervention works 104
4.8.5 Description of maintenance operations 107
5. Concrete overlays 108
5.1 Foreword 108
5.2 Basics 108
5.2.1 When to adopt this method 108
5.2.2 Materials and systems 109
5.2.3 Techniques 109
5.2.4 Equipment 110
5.3 Stakeholders' roles and qualifications 110
5.3.1 Owner 110
5.3.2 Designer 111
5.3.3 Contractor 111
5.4 Design 111
5.4.1 Assessment of existing conditions 111
5.4.2 Service life 111
5.4.3 Reliability requirements 112
5.4.4 Codes and standards and other relevant references 112
5.4.5 Design assumptions 113
5.4.6 Design procedure 113
5.5 Execution 114
5.5.1 Preparatory works 114
5.5.2 Execution procedure 114
5.6 Quality control 114
5.6.1 Quality control during intervention 114

5.7 Monitoring and maintenance 115
5.8 Literature 115
5.9 Case study 116
5.9.1 Description of the structure 116
5.9.2 Inspection highlights 116
5.9.3 Description of the intervention project 116
5.9.4 Description of the intervention works 119
5.9.5 Description of maintenance operations 119
6. Externally applied textile reinforced systems 120
6.1 Foreword 120
6.2 Basics 121
6.2.1 When to adopt this method 121
6.2.2 Materials 122
6.2.3 Techniques 122
6.2.4 Equipment 126
6.3 Stakeholders' roles and qualifications 126
6.3.1 Owner 126
6.3.2 Designer 126
6.3.3 Contractor 127
6.3.4 User 127
6.4 Design 127
6.4.1 Assessment of existing conditions 127
6.4.2 Service life 128
6.4.3 Reliability requirements 128
6.4.4 Codes and standards and other relevant references 128
6.4.5 Design assumptions 131
6.4.6 Design procedures 132
6.4.7 Supporting documents 132
6.5 Execution 132
6.5.1 Preparatory works 132
6.5.2 System trials 133
6.5.3 Execution procedure 133
6.5.4 Finishing 133
6.6 Quality control 134
6.6.1 Quality control of materials 134
6.6.2 Quality control before intervention 135
6.6.3 Quality control during intervention 135
6.6.4 Quality control after intervention 135

6.7 Monitoring and maintenance 137
6.7.1 Monitoring 137
6.7.2 Maintenance 137
6.7.3 Post-intervention documentation 137
6.8 Case study 1 138
6.8.1 Description of the structure 138
6.8.2 Inspection highlights 138
6.8.3 Description of the intervention project 139
6.8.4 Description of the intervention works 139
6.8.5 Description of maintenance operations 142
6.9 Case study 2 145
6.9.1 Description of the structure 145
6.9.2 Inspection highlights 146
6.9.3 Description of the intervention project 146
6.9.4 Description of the intervention works 149
6.9.5 Description of maintenance operations 150
6.10 Case study 3 150
6.10.1 Description of the structure 150
6.10.2 Inspection highlights 151
6.10.3 Description of the intervention project 151
6.10.4 Description of the intervention works 153
6.11 Case study 4 158
6.11.1 Description of the structure 158
6.11.2 Inspection highlights 158
6.11.3 Description of the intervention project 159
6.11.4 Description of the intervention works 159
6.11.5 Description of maintenance operations 161
7. Externally applied or near surface mounted FRP 162
7.1 Foreword 162
7.2 Basics 162
7.2.1 Applicability of these methods 162
7.2.2 Materials and systems 163
7.2.3 Techniques and strategies 164
7.3 Design 165
7.3.1 Assessment of existing conditions 165
7.3.2 Codes and standards and other relevant references 165
7.3.3 Design assumptions 166
7.3.4 Design procedure 167
7.3.5 Supporting documents 168

7.4 Stakeholders' roles and qualifications 168
7.5 Execution 169
7.5.1 Equipment and tools 169
7.5.2 Preparatory works 169
7.5.3 Execution procedure 169
7.5.4 Finishing 182
7.6 Quality control 182
7.6.1 Quality control of materials 182
7.6.2 Quality control before application 182
7.6.3 Quality control during intervention 183
7.6.4 Quality control after intervention 183
7.7 Monitoring and maintenance 183
7.8 Case study 1 183
7.8.1 Description of the structure 184
7.8.2 Description of the intervention project 184
7.8.3 Description of the strengthening procedure 185
7.9 Case study 2 188
7.9.1 Description of the structure 188
7.9.2 Strengthening program 189
7.9.3 Description of the strengthening procedure 189
7.9.4 Flexural strengthening 192
7.9.5 Shear strengthening 192
8. Strengthening foundations with steel micro-piles 194
8.1 Foreword 194
8.2 Basics 194
8.2.1 When to adopt this method 194
8.2.2 Materials and systems 195
8.2.3 Techniques 196
8.2.4 Equipment 196
8.3 Stakeholders' roles and qualifications 196
8.3.1 Owner 196
8.3.2 Designer 197
8.3.3 Contractor 197
8.3.4 User 197
8.4 Design 197
8.4.1 Assessment of existing conditions 197
8.4.2 Service life 198
8.4.3 Reliability requirements 198

8.4.4 Codes and standards and other relevant references 198
8.4.5 Design assumptions 199
8.4.6 Design procedure 199
8.4.7 Supporting documents 200
8.5 Execution 200
8.5.1 Preparatory works 200
8.5.2 System trials 200
8.5.3 Execution procedure 200
8.5.4 Finishing 200
8.6 Quality control 201
8.6.1 Quality control of materials 201
8.6.2 Quality control before intervention 201
8.6.3 Quality control during intervention 202
8.6.4 Quality control after intervention 202
8.7 Monitoring and maintenance 203
8.7.1 Monitoring 203
8.7.2 Maintenance 203
8.7.3 Post-intervention documentation 203
8.8 Case study 1 204
8.8.1 Description of the structure 204
8.8.2 Inspection highlights 204
8.8.3 Description of the intervention project 205
8.8.4 Description of the foundations strengthening works 205
8.8.5 Description of maintenance operations 207
8.9 Case study 2 207
8.9.1 Description of the structure 207
8.9.2 Inspection highlights 207
8.9.3 Description of the intervention project 207
8.9.4 Description of the foundations strengthening works 208
8.9.5 Description of maintenance operations 210
9. Impressed current cathodic protection and structural strengthening (ICCP-SS) intervention technique 211
9.1 Foreword 211
9.2 Basics 212
9.2.1 When to adopt this method 212
9.2.2 Materials and systems 212
9.2.3 Techniques 213
9.2.4 Equipment 213

9.3 Stakeholders' roles and qualifications 213
9.3.1 Owner 213
9.3.2 Designer 214
9.3.3 Contractor 214
9.3.4 User 214
9.4 Design 214
9.4.1 Assessment of existing conditions 214
9.4.2 Service life 215
9.4.3 Reliability requirements 215
9.4.4 Codes and standards and other relevant references 215
9.4.5 Design assumptions 217
9.4.6 Design procedure 217
9.4.7 Supporting documents 218
9.5 Execution 218
9.5.1 Preparatory works 218
9.5.2 System trials 219
9.5.3 Execution procedure 219
9.5.4 Finishing 220
9.6 Quality control 220
9.6.1 Quality control of materials 220
9.6.2 Quality control before intervention 220
9.6.3 Quality control during intervention 221
9.6.4 Quality control after intervention 221
9.7 Monitoring and maintenance 221
9.7.1 Monitoring 221
9.7.2 Maintenance 222
9.7.3 Post-intervention documentation 222
9.8 Case study 222
9.8.1 Description of the structure 223
9.8.2 Inspection highlights 223
9.8.3 Description of the intervention project 224
9.8.4 Description of the intervention works 227
9.8.5 Description of maintenance operations 229
9.8.6 Monitoring and review 229
9.8.7 Final remarks 230

10. Frame encasement (shear walls) 231
10.1 Foreword 231
10.2 Basics 231
10.2.1 When to adopt this method 231
10.2.2 Materials and systems 232
10.2.3 Techniques 232
10.2.4 Equipment 237
10.3 Stakeholders' roles and qualifications 237
10.3.1 Owner 237
10.3.2 Designer 238
10.3.3 Contractor 238
10.3.4 User 238
10.4 Design 238
10.4.1 Assessment of existing conditions 238
10.4.2 Service life and reliability requirements 239
10.4.3 Codes and standards and other relevant references 239
10.4.4 Design assumptions 240
10.4.5 Design procedures 241
10.4.6 Supporting documents 246
10.5 Execution 247
10.5.1 Preparatory works 247
10.5.2 System trials 247
10.5.3 Execution procedure 247
10.5.4 Finishing 248
10.6 Quality control 248
10.6.1 Quality control of materials 248
10.6.2 Quality control before intervention 248
10.6.3 Quality control during intervention 249
10.6.4 Quality control after intervention 249
10.7 Monitoring and maintenance 249
10.7.1 Monitoring 249
10.7.2 Maintenance 249
10.8 Case study 250
10.8.1 Introduction 250
10.8.2 Description of the structure 250
10.8.3 Inspection highlights 250
10.8.4 Description of the intervention project 251

10.8.5 Seismic retrofit 251
10.8.6 Calculations for new shear wall 252
10.8.7 Description of the frame encasement intervention works 262
10.8.8 References 263
11. External post-tensioning 264
11.1 Foreword 264
11.2 Basics 264
11.2.1 When to adopt this method 264
11.2.2 Prestressing elements 265
11.2.3 Materials 266
10.2.4 Prestressing equipment 267
11.3 Stakeholders' roles and qualifications 268
11.3.1 Owner 268
11.3.2 Designer 268
11.3.3 Contractor 268
11.4 Design 269
11.4.1 Assessment of existing conditions 269
11.4.2 Service life 269
11.4.3 Reliability requirements 270
11.4.4 Codes and standards and other relevant references 270
11.4.5 Design assumptions 270
11.4.6 Design procedure 271
11.4.7 Supporting documents 272
11.5 Execution 273
11.5.1 Preparatory works 273
11.5.2 System trials 273
11.5.3 Execution procedure 274
11.5.4 Finishing 274
11.6 Quality control 274
11.6.1 Quality control of materials 274
11.6.2 Quality control before intervention 275
11.6.3 Quality control during intervention 275
11.6.4 Quality control after intervention 275
11.7 Monitoring and maintenance 275
11.7.1 Monitoring 275
11.7.2 Maintenance 276
11.7.3 Post-intervention documentation 276

11.8 Case study 277
11.8.1 Introduction 277
11.8.2 Selection of post tensioning system 278
11.8.3 Execution of retrofitting work 281
118.4 Conclusions 288
12. Seismic protection techniques 289
12.1 Foreword 289
12.2 Part I – Buildings 290
12.2.1 Base isolation 290
12.2.2 Energy dissipation devices 296
12.3 Part II – Bridges 301
12.3.1 Basics 301
12.3.2 Design 304
12.3.3 Execution 306
12.4 Part III – Buildings and bridges 307
12.4.1 Quality control 307
12.4.2 Monitoring and maintenance 307