
Contents

<i>Preface to the fourth edition</i>	xv
<i>Preface to the third edition</i>	xvii
<i>Preface to the second edition</i>	xix
<i>Preface to the first edition</i>	xxi
<i>Acknowledgements</i>	xxiii
1 Philosophy of design	1
1.1 Introduction	1
1.2 Design inputs	1
1.3 Design process	10
1.4 Layout of Eurocodes	11
1.4.1 Principles and Application Rules	11
1.4.2 Nationally determined parameters and National Annexes	12
1.4.3 Annexes	13
1.4.4 Non-contradictory complementary information	13
1.4.5 Decimal point	13
1.5 Basis of design	13
1.5.1 Permissible stress design	14
1.5.2 Load factor design	15
1.5.3 Limit state design	15
1.5.3.1 Ultimate and serviceability limit states	15
1.5.3.2 Characteristic and design values	17
1.6 Summary	18
2 Basic technical and structural concepts	19
2.1 Introduction	19
2.2 Types of loading	20
2.2.1 Permanent loads	21
2.2.2 Variable actions	23
2.2.2.1 Imposed loads	23
2.2.2.2 Wind loads	23
2.2.3 Load combinations and design loads	24

- 2.3 *Design loads acting on elements* 27
- 2.4 *Structural analysis* 31
 - 2.4.1 *Equilibrium equations* 32
 - 2.4.2 *Formulae* 36
- 2.5 *Beam design* 38
 - 2.5.1 *Elastic criteria* 39
 - 2.5.2 *Plastic criteria* 40
- 2.6 *Column design* 42
- 2.7 *Summary* 43

3 Design in reinforced concrete to EN 1992

47

- 3.1 *Introduction* 47
- 3.2 *Objectives and scope* 48
- 3.3 *Symbols* 49
- 3.4 *Basis of design* 51
- 3.5 *Material properties* 51
 - 3.5.1 *Characteristic compressive strength of concrete* 52
 - 3.5.2 *Characteristic strength of reinforcement* 53
 - 3.5.3 *Design strength* 54
- 3.6 *Loading* 55
 - 3.6.1 *Characteristic load* 55
 - 3.6.2 *Design load* 55
- 3.7 *Stress–strain curves* 56
 - 3.7.1 *Stress–strain curve for concrete* 56
 - 3.7.2 *Stress–strain curve for steel reinforcement* 57
- 3.8 *Cover to bar reinforcement* 59
 - 3.8.1 *Bond* 59
 - 3.8.2 *Durability* 59
 - 3.8.3 *Fire protection* 68
- 3.9 *Beams* 70
 - 3.9.1 *Singly reinforced beam design* 71
 - 3.9.1.1 *Bending* 71
 - 3.9.1.2 *Shear* 77
 - 3.9.1.3 *Deflection* 85
 - 3.9.1.4 *Beam sizing* 88
 - 3.9.1.5 *Reinforcement details* 89
 - 3.9.2 *Doubly reinforced beam design* 106
 - 3.9.2.1 *Compression and tensile steel areas* 107
 - 3.9.3 *Continuous, L and T beams* 110
 - 3.9.3.1 *Analysis of continuous beams* 112
 - 3.9.4 *Summary for beam design* 128
- 3.10 *Slabs* 128
 - 3.10.1 *Types of slabs* 130
 - 3.10.2 *Design of one-way spanning solid slab* 134

- 3.10.2.1 Depth of slab 134
 - 3.10.2.2 Steel areas 135
 - 3.10.2.3 Shear 135
 - 3.10.2.4 Reinforcement details 136
 - 3.10.3 Continuous one-way spanning solid slab design 146
 - 3.10.4 Two-way spanning restrained solid slab design 151
- 3.11 Foundations 158
 - 3.11.1 Foundation types 159
 - 3.11.2 Foundation design 163
 - 3.11.2.1 Pad footing 163
- 3.12 Retaining walls 171
 - 3.12.1 Types of retaining walls 171
 - 3.12.1.1 Gravity walls 171
 - 3.12.1.2 Flexible walls 172
 - 3.12.2 Design of cantilever walls 173
 - 3.12.2.1 Soil pressures 173
 - 3.12.2.2 Stability 174
 - 3.12.2.3 Reinforcement areas 176
- 3.13 Design of braced columns 184
 - 3.13.1 Braced and unbraced columns 184
 - 3.13.2 Column failure modes 185
 - 3.13.3 Slenderness ratio 187
 - 3.13.4 Threshold slenderness ratio, λ_{lim} 190
 - 3.13.5 Design of braced columns 193
 - 3.13.5.1 Design of columns when $\lambda < \lambda_{lim}$ 200
 - 3.13.5.2 Design of columns when $\lambda > \lambda_{lim}$ 205
 - 3.13.6 Biaxial bending 207
 - 3.13.6.1 Manual for the design of concrete structures to Eurocode 2, IStructE, 2006 208
 - 3.13.7 Reinforcement details for columns 209
 - 3.13.7.1 Longitudinal reinforcement 209
 - 3.13.7.2 Links 209
- 3.14 Summary 217

4 Design in structural steelwork to EN 1993 and EN 1994

221

- 4.1 Introduction 221
- 4.2 Iron and steel 222
 - 4.2.1 Manufacture 222
 - 4.2.2 Material behaviour 223
- 4.3 Structural steel and steel sections 223
- 4.4 Symbols 225
- 4.5 General principles and design methods 228
- 4.6 Loading 229
- 4.7 Design strengths 230

4.8	<i>Design of steel beams and joists</i>	231
4.8.1	<i>Modes of failure</i>	231
4.8.1.1	<i>Bending</i>	231
4.8.1.2	<i>Local buckling</i>	231
4.8.1.3	<i>Shear</i>	231
4.8.1.4	<i>Shear buckling</i>	231
4.8.1.5	<i>Web bearing and buckling</i>	232
4.8.1.6	<i>Lateral torsional buckling</i>	232
4.8.1.7	<i>Deflection</i>	233
4.8.2	<i>Summary of design process</i>	233
4.8.3	<i>Initial section selection</i>	234
4.8.4	<i>Classification of section</i>	235
4.8.4.1	<i>Strength classification</i>	235
4.8.4.2	<i>Section classification</i>	235
4.8.5	<i>Shear</i>	236
4.8.6	<i>Resistance of cross sections to bending</i>	237
4.8.7	<i>Bending and shear</i>	241
4.8.8	<i>Deflection</i>	244
4.8.9	<i>Web design</i>	245
4.8.10	<i>Stiffener design</i>	250
4.8.11	<i>Lateral torsional buckling</i>	255
4.8.11.1	<i>Effective length</i>	255
4.8.11.2	<i>Lateral torsional buckling resistance</i>	256
4.8.11.3	<i>Elastic critical moment, M_{cr}</i>	257
4.8.11.4	<i>Simplified expression for λ_{LT}</i>	259
4.8.11.5	<i>Alternative method for rolled sections</i>	262
4.8.11.6	<i>Cantilever beams</i>	263
4.8.11.7	<i>Summary of design procedures</i>	265
4.9	<i>Design of compression members</i>	265
4.9.1	<i>Struts</i>	265
4.9.2	<i>Effective length/buckling length</i>	268
4.9.3	<i>Columns with bending moments</i>	272
4.9.3.1	<i>Resistance of cross sections – bending and axial force</i>	273
4.9.3.2	<i>Buckling resistance check – combined bending and axial compression</i>	274
4.9.4	<i>Column design in ‘simple’ structures</i>	280
4.9.5	<i>Summary of design procedures for compression members</i>	285
4.9.6	<i>Design of cased columns</i>	286
4.9.6.1	<i>Axially loaded columns</i>	286
4.9.6.2	<i>Cased columns subjected to combined compression and bending</i>	292
4.9.7	<i>Design of column baseplates</i>	299

4.10	<i>Floor systems for steel-framed structures</i>	303
4.10.1	<i>Composite slabs</i>	308
4.10.2	<i>Composite beams</i>	309
4.10.2.1	<i>Effective breadth of concrete slab, b_{eff}</i>	310
4.10.2.2	<i>Moment capacity</i>	310
4.10.2.3	<i>Shear capacity</i>	314
4.10.2.4	<i>Shear connectors</i>	314
4.10.2.5	<i>Longitudinal shear capacity</i>	319
4.10.2.6	<i>Deflection</i>	322
4.11	<i>Design of connections</i>	331
4.11.1	<i>Bolted connections</i>	331
4.11.2	<i>Fastener spacing and edge/end distances</i>	332
4.11.3	<i>Strength checks</i>	333
4.11.3.1	<i>Ordinary bolts</i>	333
4.11.3.2	<i>Preloaded assemblies</i>	337
4.11.4	<i>Design of bolted connections</i>	338
4.11.4.1	<i>Splice connections</i>	339
4.11.4.2	<i>Bolted beam-to-column connection using an end plate</i>	342
4.11.4.3	<i>Bolted beam-to-column connection using web cleats</i>	348
4.11.5	<i>Welded connections</i>	355
4.11.5.1	<i>Strength of welds</i>	355
4.11.5.2	<i>Design details</i>	356
4.12	<i>Summary</i>	358

5 Design in unreinforced masonry to EN 1996

363

5.1	<i>Introduction</i>	363
5.2	<i>Materials</i>	365
5.2.1	<i>Bricks</i>	366
5.2.2	<i>Blocks</i>	369
5.2.3	<i>Mortars</i>	370
5.3	<i>Masonry design</i>	372
5.4	<i>Symbols</i>	372
5.5	<i>Design of vertically loaded masonry walls</i>	375
5.5.1	<i>Ultimate design loads</i>	376
5.5.1.1	<i>Characteristic actions</i>	376
5.5.1.2	<i>Partial safety factors for loads</i>	376
5.5.2	<i>Design compressive strength of masonry</i>	377
5.5.2.1	<i>Characteristic compressive strength of masonry</i>	377
5.5.2.2	<i>Partial factor for materials</i>	381
5.5.3	<i>Capacity reduction factor</i>	382

- 5.5.3.1 Capacity reduction factor at the top and bottom of walls 382
- 5.5.3.2 Capacity reduction factor in middle of wall 386
- 5.5.4 Area reduction factor 389
- 5.5.5 Design vertical load resistance of masonry walls 389
- 5.6 Design of laterally loaded wall panels 408
 - 5.6.1 Characteristic flexural strength of masonry 408
 - 5.6.2 Orthogonal ratio 409
 - 5.6.3 Support conditions 410
 - 5.6.4 Limiting dimensions 411
 - 5.6.5 Basis of design 413
- 5.7 Summary 423

6 Design in timber to EN 1995

427

- 6.1 Introduction 427
- 6.2 Stress grading 428
- 6.3 Strength classes 430
- 6.4 Grade stresses and characteristic strengths 430
- 6.5 Design principles 436
 - 6.5.1 Basis of design 436
 - 6.5.2 Actions 437
- 6.6 Timber design 438
- 6.7 Symbols 438
- 6.8 Flexural members 440
 - 6.8.1 Effective span 440
 - 6.8.2 Bending 440
 - 6.8.3 Deflection 442
 - 6.8.4 Vibration 445
 - 6.8.5 Lateral buckling of beams 447
 - 6.8.6 Shear 449
 - 6.8.7 Compression perpendicular to the grain 450
- 6.9 Compression members 459
 - 6.9.1 Relative slenderness ratio 460
 - 6.9.2 Columns subject to axial compression 462
 - 6.9.2.1 Columns subject to axial load and bending 462
- 6.10 Design of stud walls 467
- 6.11 Summary 469

<i>Appendix A: Permissible stress and load factor design</i>	471
<i>Appendix B: Dimensions and properties of steel universal beams and columns</i>	477
<i>Appendix C: Equations 6.10, 6.10a and 6.10b in EN 1990</i>	481
<i>Appendix D: Second moment of area of a composite beam</i>	485
<i>Appendix E: References</i>	487
<i>Index</i>	491