
Contents

Notation	x
Foreword	xiii
1 Introduction	1
1.1 Aims of the <i>Manual</i>	1
1.2 Eurocode system	1
1.3 Scope of the <i>Manual</i>	3
1.4 Contents of the <i>Manual</i>	4
1.5 Notation and terminology	4
2 General principles	5
2.1 General	5
2.2 Stability	5
2.3 Robustness	6
2.4 Movement joints	6
2.5 Fire resistance	7
2.6 Durability	7
3 Design principles - reinforced concrete	8
3.1 Loading	8
3.2 Limit states	9
3.2.1 Ultimate limit state (ULS)	9
3.2.2 Serviceability limit states (SLS)	10
4 Initial design - reinforced concrete	11
4.1 Introduction	11
4.2 Loads	11
4.3 Material properties	12
4.4 Structural form and framing	12
4.5 Fire resistance	13
4.6 Durability	14
4.7 Stiffness	14
4.8 Sizing	15
4.8.1 Introduction	15
4.8.2 Loading	15
4.8.3 Width of beams and ribs	15
4.8.4 Sizes and reinforcement of columns	15
4.8.5 Walls ($h \geq 4b$)	17
4.8.6 Punching shear in flat slabs at columns	17
4.8.7 Adequacy of chosen sections to accommodate the reinforcement	18
4.8.7.1 Bending moment and shear forces	18
4.8.7.2 Provision of reinforcement	20
4.9 The next steps	21
4.10 Reinforcement estimates	21

5 Final design - reinforced concrete

23

5.1	Introduction	23
5.1.1	Checking of all information	23
5.1.2	Preparation of a list of design data	24
5.1.3	Amendment of drawings as a basis for final calculations	24
5.1.4	Final design calculations	25
5.2	Slabs	25
5.2.1	Introduction	25
5.2.2	Fire resistance and durability	26
5.2.2.1	Fire resistance	26
5.2.2.2	Durability	26
5.2.3	Bending moments and shear forces	28
5.2.3.1	General	28
5.2.3.2	One-way spanning slabs	28
5.2.3.3	Two-way spanning slabs on linear supports	29
5.2.3.4	Flat slabs	31
5.2.4	Section design - solid slabs	35
5.2.4.1	Bending	35
5.2.4.2	Shear	38
5.2.4.3	Openings	43
5.2.5	Span/effective depth ratios	43
5.2.6	Section design - ribbed and coffered slabs	43
5.2.6.1	Bending	44
5.2.6.2	Span/effective depth ratios	44
5.2.6.3	Shear	44
5.2.6.4	Beam strips in ribbed and coffered slabs	45
5.2.7	Notes on the use of precast floors	45
5.3	Structural frames	46
5.3.1	Division into subframes	46
5.3.2	Elastic analysis	47
5.3.3	Redistribution of moments	47
5.3.4	Design shear forces	48
5.4	Beams	48
5.4.1	Introduction	48
5.4.2	Fire resistance and durability	49
5.4.2.1	Fire resistance	49
5.4.2.2	Durability	50
5.4.3	Bending moments and shear forces	51
5.4.4	Section design	52
5.4.4.1	Bending	52
5.4.4.2	Minimum and maximum amounts of reinforcement	54
5.4.4.3	Shear	56
5.4.5	Span/effective depth ratios	57

5.5	Columns ($h \leq 4 b$)	57
5.5.1	Introduction	57
5.5.2	Slenderness, fire resistance and durability	58
5.5.2.1	Slenderness	58
5.5.2.2	Fire resistance	60
5.5.2.3	Durability	60
5.5.3	Axial loads and moments - columns	61
5.5.4	Axial loads and moments - slender columns	62
5.5.4.1	General	62
5.5.4.2	Calculation of first-order moments around mid height	64
5.5.4.3	Calculation of the ultimate deflection	64
5.5.5	Section design	65
5.5.6	Reinforcement	66
5.6	Walls	66
5.6.1	Introduction	66
5.6.2	Slenderness, fire resistance and durability	67
5.6.2.1	Slenderness	67
5.6.2.2	Fire resistance	68
5.6.2.3	Durability	68
5.6.3	Axial loads and moments	68
5.6.3.1	In-plane bending	68
5.6.3.2	Bending at right-angles to the walls	69
5.6.3.3	Slender walls	69
5.6.4	Section design	69
5.6.4.1	Walls not subject to significant bending at right-angles to the wall	70
5.6.4.2	Intersecting walls	70
5.6.5	Reinforcement	70
5.6.6	Openings in shear and core walls	70
5.7	Staircases	71
5.7.1	Introduction	71
5.7.2	Fire resistance and durability	71
5.7.2.1	Fire resistance	71
5.7.2.2	Durability	71
5.7.3	Bending moments and shear forces	71
5.7.4	Effective spans	71
5.7.4.1	Stairs spanning between beams or walls	71
5.7.4.2	Stairs spanning between landing slabs	72
5.7.4.3	Stairs with open wells	72
5.7.5	Span/effective depth ratios	72
5.7.6	Section design	73
5.8	Design of non-suspended ground floor slabs	73

5.9	Guidance for the design of basement walls	74
5.9.1	General	74
5.9.2	Bending moments and shear forces	74
5.9.3	Section design	74
5.9.4	Foundation	74
5.9.5	Reinforcement	74
5.10	Foundations	74
5.10.1	Introduction	74
5.10.2	Durability and cover	75
5.10.3	Types of foundation	75
5.10.4	Plan area of foundations	76
5.10.5	Design of spread footings	76
5.10.5.1	Axially loaded unreinforced spread footings	76
5.10.5.2	Axially loaded reinforced spread footings	76
5.10.5.3	Eccentrically loaded footings	77
5.10.6	Design of other footings	78
5.10.6.1	Strip footings	78
5.10.6.2	Combined footings and balanced footings	78
5.10.7	Reinforcement in footings	78
5.10.8	Design of rafts	78
5.10.9	Design of pile caps	79
5.10.10	Reinforcement in pile caps	81
5.11	Robustness	81
5.11.1	General	81
5.11.2	Tie forces and arrangements	83
5.12	Detailing	84
5.12.1	General	84
5.12.2	Bond conditions	84
5.12.3	Anchorage and lap lengths	85
5.12.4	Transverse reinforcement	88
5.12.5	Additional rules for large diameter bars	89
5.12.6	Curtailment of bars in flexural members	90
5.12.7	Corbels and nibs	90
6	Design principles - prestressed concrete	95
6.1	Introduction	95
6.2	Design principles	95
6.3	Loading	97
6.3.1	Serviceability limit state (SLS)	98
6.3.2	Ultimate limit state (ULS)	100
6.4	Materials, prestressing components	100

7 Preliminary design - prestressed concrete	104
7.1 Introduction	104
7.1.1 General	104
7.1.2 Effective lengths	104
7.1.3 Lateral buckling	104
7.1.4 Torsion	104
7.2 Loads	105
7.3 Material properties	106
7.4 Structural form and framing	106
7.5 Fire resistance and durability	108
7.6 Stiffness	109
7.6.1 Slabs	109
7.6.2 Isolated beams	112
7.7 Sizing	112
7.7.1 Introduction	112
7.7.2 Loading	112
7.7.3 Width of beams and ribs	113
7.7.4 Shear	113
7.7.4.1 General	113
7.7.4.2 Beams and slabs (single and two way)	113
7.7.4.3 Flat slabs	114
7.7.5 Adequacy of chosen sections to accommodate the tendons and reinforcement	114
7.7.5.1 Bending moments and shear forces	114
7.7.5.2 Provision of tendons and reinforcement	115
7.8 Initial design	116
7.8.1 Introduction	116
7.8.1.1 Tendon profile	116
7.8.1.2 Tendon force profile – Initial force (P_o)	116
7.8.1.3 Tendon force profile – Final force ($P_{m,\infty}$)	119
7.8.1.4 Tendon spacing	120
7.8.2 Post-tensioned anchorages	121
7.8.2.1 Anchorage zones	121
7.8.2.2 Bursting	121
7.8.2.3 Overall equilibrium	122
7.8.2.4 Spalling	124
7.8.3 Post-tensioned Couplers	124
7.9 The next steps	125
7.10 Reinforcement estimates	125
References	127
Appendix A Design data	129
Appendix B Durability	130
Appendix C Column design charts	137
Appendix D Strength and deformation properties of concrete	141

Tables

Table 3.1	Notional inclination of a structure	8
Table 3.2	Partial factors for loads γ_f at the ultimate limit state	9
Table 3.3	Serviceability load cases	10
Table 3.4	ψ factors for buildings	10
Table 4.1	Fire resistance requirements for the initial design of continuous members	13
Table 4.2	Basic ratios of span/effective depth for initial design ($f_{yk} = 500\text{MPa}$)	14
Table 4.3	Equivalent 'stress' values	16
Table 4.4	Ultimate bending moments and shear forces	18
Table 5.1	Fire resistance requirements for slabs	27
Table 5.2	Bending moments and shear forces for one-way slabs	28
Table 5.3	Bending moment coefficients for two-way spanning rectangular slabs	30
Table 5.4	Bending moment and shear force coefficients for flat slab panels of three or more equal spans	32
Table 5.5	Distribution of design moments of flat slabs	32
Table 5.6	Alternative requirements to control crack widths to 0.3mm for members reinforced with high bond bars	38
Table 5.7	Ultimate shear stress $v_{Rd,c}$	41
Table 5.8	Span/effective depth ratios for slabs	44
Table 5.9	Effective widths of flanged beams	46
Table 5.10	Fire resistance requirements for simply supported beams	50
Table 5.11	Fire resistance requirements for continuous beams	51
Table 5.12	Bending moments and shear forces for beams at ultimate limit state	52
Table 5.13	Span/effective depth ratios for beams	58
Table 5.14	Effective height, l_0 , factors for columns	60
Table 5.15	Fire resistance requirements for columns with rectangular or circular section	61
Table 5.16	Bending moments at around mid-height in slender columns	63
Table 5.17	Design moments for biaxial bending	65
Table 5.18	Coefficients for biaxial bending	66
Table 5.19	Effective height factors for walls	67
Table 5.20	Fire resistance requirements for walls	68
Table 5.21	Span/effective depth ratios for stairs	73
Table 5.22	Depth/projection ratios for unreinforced footings	76

Table 5.23	Reinforcement percentages, depth/projection ratios and unfactored ground pressures for reinforced footings for $f_{ck} = 25\text{MPa}$	77
Table 5.24	Typical values of anchorage and lap lengths for slabs	86
Table 5.25	Typical values of anchorage and lap lengths for beams	86
Table 5.26	Typical values of anchorage and lap lengths for columns	87
Table 5.27	Typical values of anchorage and lap lengths for walls	87
Table 6.1	Advantages and disadvantages of pre- and post-tensioning	96
Table 6.2	Advantages and disadvantages of bonded and unbonded construction	96
Table 6.3	Typical dimensional data for common post-tensioning systems for slabs	101
Table 6.4	Typical dimensional data for common post-tensioning systems (1 to 19 strands)	102
Table 7.1	Strand loads (after losses) to be used for initial design	106
Table 7.2	Minimum member sizes and axis distances for prestressed members in fire	108
Table 7.3	Minimum cover to curved ducts	109
Table 7.4	Typical span/depth ratios for a variety of section types for multi-span floors	110
Table 7.5	Span/effective depth ratios for initial sizing of isolated beams	112
Table 7.6	Moment coefficients for two-way solid slabs on linear supports	114
Table 7.7	Allowable stresses for initial design	115
Table 7.8	Maximum jacking loads per strand	118
Table 7.9	Elastic modulus of concrete	119
Table 7.10	Shrinkage strains for strength class C35/45	119
Table 7.11	Creep coefficients	119
Table 7.12	Minimum distance between centre-lines of ducts in plane of curvature	120
Table 7.13	Design bursting tensile forces in anchorage zones	121
Table B.1	Exposure classes related to environmental conditions in accordance with BS EN 206-1	130
Table B.2	Recommendations for normal-weight concrete quality for selected exposure classes and cover to reinforcement for a 50 year intended working life and 20mm maximum aggregate size	133
Table B.3	Recommendations for normal-weight concrete quality for selected exposure classes and cover to reinforcement for a 100 year intended working life and 20mm maximum aggregate size	135
Table D.1	Strength and deformation properties of concrete	141