Contents

Foreword	v
List of Figures	xiii
List of Tables	xvii

Chapter 1 Design of Steel Structures

1.1	Introduction to Structural Design	1
1.2	Evaluation of Sustainability	2
1.3	Structure of Structural Steel Standards	5
1.4	Reliability in Design Standards	11
1.5	European Standards for Execution	14
1.6	Assessment of Existing Structures	15

Chapter 2 General Rules and Rules for Buildings

2.1	Gener	al	19
	2.1.1	Extent of validity	19
		2.1.1.1 Validity of Eurocode 3	19
		2.1.1.2 Validity of part 1-1	19
	2.1.2	Normative references	19
	2.1.3	Assumptions	19
	2.1.4	Distinction between principles and application rules	19
	2.1.5	Terms and definitions	20
	2.1.6	Symbols	20
2.2	Basis o	f Design	20
	2.2.1	Requirements	20
		2.2.1.1 Basic requirements	20
		2.2.1.2 Reliability management	21
		2.2.1.3 Design working life, durability and robustness	21
	2.2.2	Principles of limit state design	21

viii Design of Steel Structures with Worked Examples to EN 1993-1-1 and EN 1993-1-8

	2.2.3	Basic vari	ables	21
		2.2.3.1	Actions and environmental influences	21
		2.2.3.2	Material and product properties	22
	2.2.4	Verificatio	on by the partial factor method	22
		2.2.4.1	Design values of material properties	22
		2.2.4.2	Design values of geometrical data	22
		2.2.4.3	Design resistances	22
		2.2.4.4	Verification of static equilibrium (EQU)	22
	2.2.5	Design as	ssisted by testing	22
2.3	Materio	als		23
	2.3.1	General		23
	2.3.2	Structura	steel	23
		2.3.2.1	Material properties	23
		2.3.2.2	Ductility requirements	23
		2.3.2.3	5	23
		2.3.2.4	Through-thickness properties	25
		2.3.2.5		26
		2.3.2.6	Design values of material coefficients	26
	2.3.3		ng devices	26
		2.3.3.1	Fasteners	26
		2.3.3.2	Welding consumables	26
	2.3.4	Other pre	efabricated products in buildings	26
2.4	Durabi	lity		27
2.5	Structu	ral Analysi	s	27
	2.5.1	Structura	l modelling for analysis	27
		2.5.1.1	Structural modelling and basic assumptions	27
		2.5.1.2	Joint modelling	27
		2.5.1.3	Ground-structure interaction	27
	2.5.2	Global ar	nalysis	28
		2.5.2.1	Effects of deformed geometry of the structure	28
		2.5.2.2	Structural stability of frames	30
	2.5.3	Imperfect	ions	31
		2.5.3.1	Basis	31
		2.5.3.2	Imperfections for global analysis of frames	31
		2.5.3.3	Imperfection for analysis of bracing systems	35
		2.5.3.4	Member imperfections	37
	2.5.4		of analysis considering material non-linearities	37
		2.5.4.1	General	37
		2.5.4.2	Elastic global analysis	38
		2.5.4.3	Plastic global analysis	38
	2.5.5	Classifica	tion of cross sections	38

		2.5.5.1 2.5.5.2	Basis Classification	38 38
	2.5.6	Cross-sec	tion requirements for plastic global analysis	40
2.6	Ultimate Limit State			40
	2.6.1	General		40
	2.6.2	Resistance	e of cross-sections	40
		2.6.2.1	General	40
		2.6.2.2	Section properties	44
		2.6.2.3	Tension	46
		2.6.2.4	Compression	47
		2.6.2.5	Bending moment	47
		2.6.2.6	Shear	48
		2.6.2.7	Torsion	49
		2.6.2.8	Bending moment and shear	51
		2.6.2.9	5	52
		2.6.2.10	Bending, shear and axial force	54
	2.6.3	Buckling	resistance of members	54
		2.6.3.1	Uniform members in compression	54
		2.6.3.2	Uniform members in bending	59
		2.6.3.3	Uniform members in bending and axial compression	66
		2.6.3.4	General method for lateral and lateral torsional buckling	68
		2.6.3.5	Lateral torsional buckling of members with plastic hinges	70
	2.6.4	Uniform l	ouilt-up compression members	72
		2.6.4.1	General	72
		2.6.4.2	Laced compression members	74
		2.6.4.3	Battened Compression Members	75
		2.6.4.4	Closely Spaced Built-up Members	77
2.7	Service	ability Lim	it States	78
	2.7.1	General a	conditions	78
	2.7.2	Ultimate	limit states for buildings	78
		2.7.2.1	Vertical deflections	78
		2.7.2.2	Horizontal deflections	79
		2.7.2.3	Vibrations	79

Chapter 3 Connections Design

3.1	Introduction	81
3.2	Basis of Design	81

x Design of Steel Structures with Worked Examples to EN 1993-1-1 and EN 1993-1-8

	3.2.1	Assumptio	ons	81
	3.2.2	General r	equirements	81
	3.2.3	Applied for	orces and moments	81
	3.2.4	Resistance	e of joints	81
	3.2.5	Design as	sumptions	82
	3.2.6	Joints load load reve	ded in shear subject to impact, vibration and/or rsal	82
	3.2.7	Eccentricit	ty at intersections	83
3.3	Connec	tions Mad	e with Bolts, Rivets or Pins	83
	3.3.1	Bolts, nut	s and washers	83
		3.3.1.1	General	83
		3.3.1.2	Preloaded bolts	83
	3.3.2	Rivets		83
	3.3.3	Anchor bo	olts	83
	3.3.4	•	es of bolted connections	84
		3.3.4.1	Shear connections	84
		3.3.4.2	Tension connections	84
	3.3.5		g of holes for bolts and rivets	84
	3.3.6	0	sistance of individual fasteners	85
		3.3.6.1 3.3.6.2	Bolts and rivets Injection bolts	85 89
	337	Group of	-	89
	3.3.8	Long joint		90
	3.3.9	• •	ant connections using 8.8 or 10.9 bolts	90
	5.5.7	3.3.9.1	Design slip resistance	90 90
		3.3.9.2		91
		3.3.9.3	Hybrid connections	91
	3.3.10		ns for fastener holes	92
			General	92
			Design for block tearing	92
		3.3.10.3	Angles connected by one leg and other unsymmetrically connected members in tension	93
		3.3.10.4	Lug angles	93
	3.3.11	Prying for	ces	94
			on of forces between fasteners at the ultimate	94
	3.3.13	Connectio	ons made with pins	95
3.4		l Connectio	·	95
		General		95

3.4.2	Welding	consumables	95
3.4.3	Geometr	y and dimensions	95
	3.4.3.1	Type of weld	95
	3.4.3.2	Fillet welds	95
	3.4.3.3	Fillet welds all round	96
			96
		•	96
	3.4.3.6	Flare groove welds	97
3.4.4	Welds wi	th packings	98
3.4.5	Design re	esistance of a fillet weld	98
	3.4.5.1	Length of welds	98
	3.4.5.2		98
	3.4.5.3	Design Resistance of fillet welds	99
3.4.6	Design resistance of fillet welds all round		100
3.4.7	Design re	esistance of butt welds	100
	3.4.7.1	Full penetration butt welds	100
	3.4.7.2	Partial penetration butt welds	101
	3.4.7.3	T-butt joints	101
3.4.8	Design resistance of plug welds		101
3.4.9	Distribution of forces		101
3.4.10) Connections to unstiffened flanges		
3.4.11	1 Long joints		
3.4.12	Eccentric	ally loaded fillet or partial penetration butt welds	103
3.4.13	Angles co	onnected by one leg	104
Analysi	s, Classifi	cation and Modelling	104
Open S	Sections Jo	pints	105
Hollow Section Joints			106
	3.4.3 3.4.4 3.4.5 3.4.6 3.4.7 3.4.7 3.4.7 3.4.10 3.4.11 3.4.12 3.4.13 Analysi Open S	 3.4.3 Geometri 3.4.3.1 3.4.3.1 3.4.3.2 3.4.3.3 3.4.3.4 3.4.3.5 3.4.3.6 3.4.4 Welds with 3.4.5 Design ref 3.4.5.1 3.4.5 Design ref 3.4.5.3 3.4.6 Design ref 3.4.7 Design ref 3.4.7 Design ref 3.4.7.1 3.4.7 Design ref 3.4.7.3 3.4.8 Design ref 3.4.9 Distributi 3.4.10 Connectin 3.4.11 Long join 3.4.12 Eccentric 3.4.13 Angles con Analysis, Classific Open Sections Joint 3.4.10 	 3.4.3.1 Type of weld 3.4.3.2 Fillet welds 3.4.3.3 Fillet welds all round 3.4.3.4 Butt welds 3.4.3.5 Plug welds 3.4.3.6 Flare groove welds 3.4.4 Welds with packings 3.4.5 Design resistance of a fillet weld 3.4.5.1 Length of welds 3.4.5.2 Effective throat thickness 3.4.5.3 Design Resistance of fillet welds 3.4.6 Design resistance of butt welds all round 3.4.7 Design resistance of butt welds 3.4.7.1 Full penetration butt welds 3.4.7.2 Partial penetration butt welds 3.4.7.3 T-butt joints 3.4.8 Design resistance of plug welds 3.4.10 Connections to unstiffened flanges 3.4.11 Long joints 3.4.12 Eccentrically loaded fillet or partial penetration butt welds 3.4.13 Angles connected by one leg Analysis, Classification and Modelling Open Sections Joints

Chapter 4 Worked Examples

4.1	Selection of Material for Fracture Toughness (A Steel Subgrade)	109
4.2	Selection of Material for Lamellar Tearing, through Thickness Properties	113
4.3	Tensile Chord of Truss Girder from Angles	113
4.4	Design of a Column with Intermediate Supports	114
4.5	Secondary Beam Laterally Restrained	118
4.6	Cantilever Beam Bending	120
4.7	Portal Frame	123

xii Design of Steel Structures with Worked Examples to EN 1993-1-1 and EN 1993-1-8

4.8	Built-up	Battened	Member	136
4.9	Lateral-Torsional Buckling of Beams			141
,	4.9.1 LTBeam software			142
	4.9.2		r beam design	146
	,.2	4.9.2.1	Forked support of an end cross-section to prevent lateral-torsional buckling	146
		4.9.2.2	Free cantilever beam end without support	148
	4.9.3	Transverse cross-sect	al support of the upper flange of an end ion	149
	4.9.4	Beam with	n end moments and transversal load	150
	4.9.5		n end moments, transversal load and ate support	154
		4.9.5.1	Elastic continuous support of one of the flanges	154
		4.9.5.2	Critical load for various alternatives of	155
		4.9.5.3	intermediate support Evaluation of a beam for a chosen variant	155
4 10	Torsion	of Open (Cross-Section Member	157
1.10		•	cross-section	157
		-	lugtion in ULS	159
			ility limit state	164
4.11			Cross-Section Member	164
		· ·	the ultimate limit state	165
			n of the serviceability limit state	167
4 12			n of Double Angle Bar	167
			-	169
			on of Double Angle Bar 	
4.14	Header	Plate Con	nection	170
4.15	Fin Plat	e Connect	ion	171