

Contents

List of Fact Sheets *xi*

Preface *xiii*

About the Author *xv*

Symbols and Abbreviations *xvii*

1	Timber as a Structural Material	1
1.1	Building with Timber: Advantages and Challenges	1
1.2	Mechanical Properties of Solid Timber	2
1.2.1	Influence of the Fibre Direction	3
1.2.2	Strength Values of Solid Timber	3
1.2.3	Deformation Properties of Solid Timber	5
1.2.4	Influence of Load Duration and Humidity	8
1.3	Wood-based Products	10
1.3.1	Solid Structural Timber and Glued Solid Timber	10
1.3.2	Glued Laminated Timber	11
1.3.3	Cross-laminated Timber	13
1.4	Wood-based Materials	14
1.4.1	Laminated Veneer Lumber	14
1.4.2	Plywood	14
1.4.3	Oriented Strand Boards	15
1.4.4	Particle Boards	15
1.4.5	Fibreboards	16
	References	17
	Standards and Technical Building Regulations	17
2	Structural Design of Beam-type Members	19
2.1	Basics of Structural Design	19
2.1.1	Action Combinations	21
2.1.2	Modification Factors and Deformation Factors	22
2.2	Bending	23
2.3	Shear	25
2.4	Torsion and Rolling Shear	26

2.5	Buckling	27
2.5.1	Lateral Flexural Buckling: k_c Method	29
2.5.2	Lateral Torsional Buckling: k_m Method	32
2.5.3	Torsional Flexural Buckling	38
2.5.4	Calculation According to the Second-Order Theory	39
2.6	Tension and Bending	40
2.7	Serviceability Limit State	41
2.7.1	Deformations	41
2.7.2	Vibrations	43
	References	44
	Standards and Technical Building Regulations	44
3	Stresses Perpendicular to the Grain	45
3.1	Introduction	45
3.2	Compression	45
3.2.1	Compression Perpendicular to the Grain	45
3.2.2	Compression Stresses at an Angle to the Grain	48
3.3	Tension Perpendicular to Grain	51
3.3.1	Overview	51
3.3.2	Notches	52
3.3.3	Tension-Loaded Connections Perpendicular to the Grain	54
3.3.4	Holes in Glulam Beams	57
	Reference	59
4	Dowel-type Connections	61
4.1	Introduction	61
4.2	Connections with Dowel-type Fasteners	62
4.2.1	Overview	62
4.2.2	Deformation Behaviour	62
4.2.3	Basics of the Calculation of Shear-Loaded Connections	65
4.2.4	Shear-Loaded Timber–Timber Connections	68
4.2.5	Shear-Loaded Timber–Timber Connections: Simplified Calculation	71
4.2.6	Shear-Loaded Steel–Timber Connections	71
4.2.7	Shear-Loaded Steel–Timber Connections: Simplified Calculation	74
4.3	Dowels and Bolts	75
4.4	Nails and Staples	77
4.4.1	Overview	77
4.4.2	Construction Rules for Connections with Nails	81
4.4.3	Construction Rules for Staples	84
4.4.4	Load-Bearing Capacity	86
4.5	Connections with Screws	89
4.5.1	Overview	89
4.5.2	Conceptual Design of Connections with Screws	90
4.5.3	Load-Bearing Capacity	93
4.5.4	Application Examples and Execution	96

4.6	Block Shear	97
4.7	Reinforcement of Dowelled Connections	99
4.8	Connections with Cross-laminated Timber (CLT)	101
	References	104
	Standards and Technical Building Regulations	105
5	Other types of connections	107
5.1	Shear Connectors	107
5.1.1	Mechanism	107
5.1.2	Connector Types and Construction Rules	107
5.1.3	Load-Bearing Capacity	112
5.2	Carpentry Connections	116
5.2.1	Overview	116
5.2.2	Halving Joints	121
5.2.3	Step Joints	124
5.2.4	Mortise and Tenon	127
5.2.5	Deformations: Slip Moduli	130
5.3	Hinged and Moment-Resistant Connections	131
5.3.1	Structural Detailing and Calculation Modelling	131
5.3.2	Method of Sections	136
5.4	Adhesive-Bonded Connections	139
5.4.1	Overview	139
5.4.2	Adhesive Bonding of Structural Elements	141
5.4.3	Connections and Repair	145
5.5	Reinforcement Against Tension Forces Perpendicular to the Grain	148
5.5.1	Notches	148
5.5.2	Connections Perpendicular to the Grain	151
5.5.3	Holes in Glulam Beams	152
	References	154
	Standards and Technical Building Regulations	155
6	Structural Elements: Beam-Type Members	157
6.1	Glulam Beams	157
6.1.1	Bending Stresses	159
6.1.2	Tension Stresses Perpendicular to the Grain	166
6.2	Trusses	170
6.3	Composite Elements	172
6.3.1	Beams, Slab and Roof Elements	172
6.3.1.1	Application of the γ -method	172
6.3.1.2	Thin-webbed Beams: Single Web and Box type	176
6.3.1.3	Thin-flanged Beam: Effective Width	178
6.3.1.4	Box-Type Section with Interlayer	181
6.3.2	Timber-concrete Composites (TCC)	182
6.3.3	Columns	187
6.3.3.1	Overview	187

6.3.3.2	Spaced Columns with Continuously Connected Shafts	189
6.3.3.3	Spaced Columns with Packs and Gussets	190
6.3.3.4	Lattice Columns with Glued or Nailed Joints	192
6.4	Bracing: Design and Detailing	192
6.4.1	Overview	192
6.4.2	Roof Structures	195
6.4.3	Beams and Columns	198
6.5	Modelling of Beam-Type Elements	206
	References	208
	Standards and Technical Building Regulations	208
	Product Information (Examples)	209
7	Structural Elements – Plane	211
7.1	Light-frame Elements	211
7.1.1	Overview	211
7.1.2	Wall Elements	213
7.1.3	Slab Elements – Diaphragms	216
7.1.4	Connections and Anchoring	218
7.2	Cross-laminated Timber (CLT)	220
7.2.1	Production, Load-bearing Characteristics and Strength	220
7.2.2	Plates	224
7.2.2.1	Bending and Shear Stiffness	224
7.2.2.2	Uniaxial Load Bearing	227
7.2.2.3	Biaxial Load Bearing	229
7.2.2.4	Single Loads	229
7.2.2.5	Deflections	232
7.2.3	Wall Panels	233
7.2.3.1	In-plane Stiffness	233
7.2.3.2	In-plane Shear	234
7.2.3.3	Axial and Combined Stresses	235
7.2.4	Detailing and Load Transfer	237
7.3	Modelling of Plane Elements	240
7.3.1	CLT Plates	240
7.3.2	Shear Walls	241
7.3.2.1	Light-frame Wall Elements	241
7.3.2.2	CLT Wall Elements	243
7.4	Interaction of Diaphragms and Bracing Walls	244
	References	247
	Product Information (Examples)	248
8	Dynamic Behaviour of Timber Structures	249
8.1	Dynamics and Vibration	249
8.1.1	Structures Under Dynamic Impact	249
8.1.2	Natural Frequencies of Simple Systems	252
8.2	Vibration of Slabs	256

8.3	Structures Under Earthquake Impact	259
8.3.1	Earthquake Impact and Energy Dissipation	260
8.3.2	Conceptual Design and Calculation	263
8.3.2.1	Force-based Approach (Lateral Force Method)	266
8.3.2.2	Performance-based Design (Non-linear Static Analysis)	266
8.3.2.3	Response History Analysis (Non-linear Dynamic Analysis)	267
8.3.3	Response Spectra Procedure – Equivalent Load	267
8.3.4	Verification of Wall and Slab Elements	278
	References	281
	Standards and Technical Building Regulations	282
9	Durability and Fire Protection	283
9.1	Durability	283
9.1.1	Overview	283
9.1.2	Durability of Wood Species	286
9.1.3	Constructive Measures Against Biological Attack	286
9.1.4	Encapsulated Construction	290
9.1.5	Wood Treatment	291
9.2	Resistance to Corrosion	293
9.3	Fire Protection	294
9.3.1	Overview	294
9.3.2	Terminology and Legal Regulations	295
9.3.3	Building Classes	296
9.3.4	Classification and Requirements for Structural Elements and Materials	297
9.4	Calculation of Fire Resistance Time	300
9.4.1	Effective Cross section Method	300
9.4.2	Connections	303
	References	305
	Standards and Technical Building Regulations	305
10	Conceptual Design	307
10.1	Multi-storey Timber Buildings	307
10.1.1	Overview	307
10.1.2	Design Criteria	307
10.2	Roof Structures	311
10.2.1	Overview	311
10.2.2	Criteria for Conceptual Design	312
10.2.3	Primary and Secondary Load-bearing Elements	315
10.2.4	Beams and Columns	316
10.2.5	Arches, Cables and Domes	318
10.3	Bridges	322
10.3.1	Overview	322
10.3.2	Design Criteria	325
10.3.3	Actions	331

10.3.4	Load Transfer	333
10.3.5	Maintenance	335
	References	336
	Standards and Technical Building Regulations	338

11 Supplementary Theoretical Background 341

11.1	Strength and Size Effect	341
11.2	Fracture Mechanics: Brittle Failure	344
11.2.1	B- and D-regions	344
11.2.2	Linear-elastic Fracture Mechanics: Energy-based Fracture Criterion	345
11.2.3	Application of Fracture Mechanics	349
11.3	Theory of Plasticity	350
11.3.1	Overview	350
11.3.2	Application of the Upper Bound Theorem	351
11.3.3	Application of the Lower Bound Theorem	352
11.3.4	Capacity Design	353
11.4	Calculation Methods for Composite Beams: γ -procedure	353
11.5	Volkersen's Theory for Adhesive Bonded Connections	358
11.6	Calculation According to Second-order Theory	361
	References	365

Index 367