

TABLE OF CONTENTS

FOREWORD	xiii
-----------------	------

PREFACE	xv
----------------	----

Chapter 1

INTRODUCTION	1
---------------------	----------

1.1. General Observations	1
---------------------------	---

1.2. Codes of Practice and Normalization	3
--	---

1.2.1. Introduction	3
---------------------	---

1.2.2. Eurocode 3	6
-------------------	---

1.2.3. Other standards	7
------------------------	---

1.3. Basis of Design	8
----------------------	---

1.3.1. Basic concepts	8
-----------------------	---

1.3.2. Reliability management	9
-------------------------------	---

1.3.3. Basic variables	13
------------------------	----

1.3.3.1. <i>Introduction</i>	13
------------------------------	----

1.3.3.2. <i>Actions and environmental influences</i>	13
--	----

1.3.3.3. <i>Material properties</i>	14
-------------------------------------	----

1.3.3.4. <i>Geometrical data</i>	15
----------------------------------	----

1.3.4. Ultimate limit states	15
------------------------------	----

1.3.5. Serviceability limit states	16
------------------------------------	----

1.3.6. Durability	18
-------------------	----

1.3.7. Sustainability	19
-----------------------	----

1.4. Materials	21
----------------	----

TABLE OF CONTENTS

1.4.1. Material specification	21
1.4.2. Mechanical properties	22
1.4.3. Toughness and through thickness properties	25
1.4.4. Fatigue properties	27
1.4.5. Corrosion resistance	27
1.5. Geometric Characteristics and Tolerances	28

Chapter 2

STRUCTURAL ANALYSIS 33

2.1. Introduction	33
2.2. Structural Modelling	34
2.2.1. Introduction	34
2.2.2. Choice of member axis	36
2.2.3. Influence of eccentricities and supports	38
2.2.4. Non-prismatic members and members with curved axis	39
2.2.5. Influence of joints	44
2.2.6. Combining beam elements together with two and three dimensional elements	51
2.2.7. Worked examples	52
2.3. Global Analysis of Steel Structures	75
2.3.1. Introduction	75
2.3.2. Structural stability of frames	77
2.3.2.1. Introduction	77
2.3.2.2. Elastic critical load	80
2.3.2.3. 2 nd order analysis	86
2.3.3. Imperfections	87
2.3.4. Worked example	93
2.4. Classification of Cross Sections	108

Chapter 3

DESIGN OF MEMBERS	115
3.1. Introduction	115
3.1.1. General	115
3.1.2. Resistance of cross sections	116
3.1.2.1. <i>General criteria</i>	116
3.1.2.2. <i>Section properties</i>	117
3.1.3. Buckling resistance of members	121
3.2. Tension	121
3.2.1. Behaviour in tension	121
3.2.2. Design for tensile force	123
3.2.3. Worked examples	126
3.3. Laterally Restrained Beams	134
3.3.1. Introduction	134
3.3.2. Design for bending	135
3.3.2.1. <i>Elastic and plastic bending moment resistance</i>	135
3.3.2.2. <i>Uniaxial bending</i>	137
3.3.2.3. <i>Bi-axial bending</i>	138
3.3.2.4. <i>Net area in bending</i>	139
3.3.3. Design for shear	139
3.3.4. Design for combined shear and bending	140
3.3.5. Worked examples	142
3.4. Torsion	154
3.4.1. Theoretical background	154
3.4.1.1. <i>Introduction</i>	154
3.4.1.2. <i>Uniform torsion</i>	156
3.4.1.3. <i>Non-uniform torsion</i>	157

TABLE OF CONTENTS

3.4.1.4. <i>Cross section resistance in torsion</i>	161
3.4.2. Design for torsion	164
3.4.3. Worked examples	166
3.5. Compression	172
3.5.1. Theoretical background	172
3.5.1.1. <i>Introduction</i>	172
3.5.1.2. <i>Elastic critical load</i>	172
3.5.1.3. <i>Effect of imperfections and plasticity</i>	177
3.5.2. Design for compression	183
3.5.3. Worked examples	188
3.6. Laterally Unrestrained Beams	197
3.6.1. Introduction	197
3.6.2. Lateral-torsional buckling	197
3.6.2.1. <i>Introduction</i>	197
3.6.2.2. <i>Elastic critical moment</i>	198
3.6.2.3. <i>Effect of imperfections and plasticity</i>	208
3.6.3. Lateral-torsional buckling resistance	210
3.6.4. Worked examples	214
3.7. Beam-Columns	223
3.7.1. Introduction	223
3.7.2. Cross section resistance	224
3.7.2.1. <i>Theoretical background</i>	224
3.7.2.2. <i>Design resistance</i>	227
3.7.3. Buckling resistance	230
3.7.3.1. <i>Theoretical background</i>	230
3.7.3.2. <i>Design resistance</i>	233
3.7.4. Worked examples	242

Chapter 4

ELASTIC DESIGN OF STEEL STRUCTURES	271
4.1. Introduction	271
4.2. Simplified Methods of Analysis	273
4.2.1. Introduction	273
4.2.2. Amplified sway-moment method	275
4.2.3. Sway-mode buckling length method	277
4.2.4. Worked example	278
4.3. Member Stability of Non-prismatic Members and Components	288
4.3.1. Introduction	288
4.3.2. Non-prismatic members	288
4.3.3. Members with intermediate restraints	293
4.3.4. General method	299
4.3.5. Worked example	302
4.4. Design Example 1: Elastic Design of Braced Steel-Framed Building	317
4.4.1. Introduction	317
4.4.2. Description of the structure	318
4.4.3. General safety criteria, actions and combinations of actions	321
4.4.3.1. <i>General safety criteria</i>	321
4.4.3.2. <i>Permanent actions</i>	321
4.4.3.3. <i>Imposed loads</i>	321
4.4.3.4. <i>Wind actions</i>	322
4.4.3.5. <i>Summary of basic actions</i>	329
4.4.3.6. <i>Frame imperfections</i>	329
4.4.3.7. <i>Load combinations</i>	332
4.4.3.8. <i>Load arrangement</i>	334

TABLE OF CONTENTS

4.4.4. Structural analysis	335
4.4.4.1. <i>Structural model</i>	335
4.4.4.2. <i>Linear elastic analysis</i>	336
4.4.4.3. <i>Susceptibility to 2nd order effects: elastic critical loads</i>	336
4.4.4.4. <i>2nd order elastic analysis</i>	338
4.4.5. Design checks	339
4.4.5.1. <i>General considerations</i>	339
4.4.5.2. <i>Cross section resistance</i>	341
4.4.5.3. <i>Buckling resistance of beams</i>	342
4.4.5.4. <i>Buckling resistance of columns and beam-columns</i>	342

Chapter 5

PLASTIC DESIGN OF STEEL STRUCTURES **343**

5.1. General Rules for Plastic Design	343
5.1.1. Introduction	343
5.1.2. Plastic limit analysis: method of mechanisms	344
5.1.3. Code requirements for plastic analysis	349
5.2. Methods of Analysis	352
5.2.1. Introduction	352
5.2.2. Approximate methods for pre-design	352
5.2.3. Computational analysis	364
5.2.4. 2 nd order effects	369
5.2.4.1. <i>Introduction</i>	369
5.2.4.2. <i>Elastic critical load</i>	369
5.2.4.3. <i>2nd order computational analysis</i>	372
5.2.4.4. <i>Simplified methods for analysis</i>	373
5.2.5. Worked example	375

TABLE OF CONTENTS

5.3. Member Stability and Buckling Resistance	385
5.3.1. Introduction	385
5.3.2. General criteria for the verification of the stability of members with plastic hinges	385
5.3.3. Bracings	386
5.3.4. Verification of the stability of members with plastic hinges	389
5.3.4.1. <i>Introduction</i>	389
5.3.4.2. <i>Prismatic members constituted by hot-rolled or equivalent welded I sections</i>	390
5.3.4.3. <i>Haunched or tapered members made of rolled or equivalent welded I sections</i>	392
5.3.4.4. <i>Modification factors for moment gradients in members laterally restrained along the tension flange</i>	395
5.3.5. Worked examples	397
5.4. Design Example 2: Plastic Design of Industrial Building	407
5.4.1. Introduction	407
5.4.2. General description	408
5.4.3. Quantification of actions, load combinations and general safety criteria	408
5.4.3.1. <i>General criteria</i>	408
5.4.3.2. <i>Permanent actions</i>	409
5.4.3.3. <i>Imposed loads</i>	409
5.4.3.4. <i>Snow loads</i>	409
5.4.3.5. <i>Wind loads</i>	410
5.4.3.6. <i>Summary of basic actions</i>	415
5.4.3.7. <i>Imperfections</i>	415
5.4.3.8. <i>Load combinations</i>	416
5.4.4. Pre-design	418

TABLE OF CONTENTS

5.4.5. Structural analysis	421
5.4.5.1. <i>Linear elastic analysis</i>	421
5.4.5.2. <i>2nd order effects</i>	423
5.4.5.3. <i>Elastic-plastic analysis</i>	424
5.4.6. Code checks	426
5.4.6.1. <i>General considerations</i>	426
5.4.6.2. <i>Cross section resistance</i>	426
5.4.6.3. <i>Buckling resistance of the rafters</i>	426
5.4.6.4. <i>Buckling resistance of the columns</i>	429
5.4.7. Synthesis	429
REFERENCES	431
