



# Design of Steel Structures

## 2<sup>nd</sup> Edition

Eurocode 3: Design of Steel Structures  
Part 1-1: General rules and rules for buildings

Luís Simões da Silva  
Rui Simões  
Helena Gervásio



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ECCS Eurocode Design Manuals

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# **DESIGN OF STEEL STRUCTURES**

**2<sup>nd</sup> EDITION**

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## FOREWORD

The development program for the design manuals of the European Convention for Constructional Steelwork (ECCS) represents a major effort for the steel construction industry and the engineering profession in Europe. Conceived by the ECCS Technical Activities Board under the leadership of its chairman, Professor Luis Simões da Silva, the manuals are being prepared in close agreement with the final stages of Eurocode 3 and its national Annexes. The scope of the development effort is vast, and reflects a unique undertaking in the world.

The publication of the first of the manuals, *Design of Steel Structures*, is a signal achievement which heralds the successful completion of the Eurocode 3 work and brings it directly to the designers who will implement the actual use of the code. As such, the book is more than a manual – it is a major textbook that details the fundamental concepts of the code and their practical application. It is a unique publication for a major construction market.

Following a discussion of the Eurocode 3 basis of design, including the principles of reliability management and the limit state approach, the steel material standards and their use under Eurocode 3 are detailed. Structural analysis and modeling are presented in a chapter that will assist the design engineer in the first stages of a design project. This is followed by a major chapter that provides the design criteria and approaches for the various types of structural members. The theories of behavior and strength are closely tied to the Eurocode requirements, making for a unique presentation of theory into practice. The following chapters expand on the principles and applications of elastic and plastic design of steel structures.

The many design examples that are presented throughout the book represent a significant part of the manual. These will be especially well received by the design profession. Without a doubt, the examples will facilitate the acceptance of the code and provide for a smooth transition from earlier national codes to the Eurocode.

**Reidar Bjorhovde**

Member, ECCS Editorial Board

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## PREFACE 2<sup>nd</sup> EDITION

The first edition of Design of Steel Structures was published by ECCS as a paperback in 2010. Since 2012, this publication is also available in electronic format as an e-book. The first edition was sold in over 100 countries and the interest for this publication was so high that a second edition would have to be printed.

The authors took the opportunity of this second edition to revise their manuscript. The standard that constitutes the object of this book, namely EN 1993-1-1, is still in application in the same versions as those that prevailed at the time of writing the first edition except for a minor amendment published in 2013. However, many comments were received by readers that resulted in the correction of some small mistakes and the rephrasing of some sentences or sections and the addition of some new material.

The new material comprises:

- A revised section dealing with the design for torsion of steel members, including a new worked example illustrating an open cross section beam subject to bending and torsional moments;
- A revised section on the elastic critical moment of beams;
- An improved explanation on the classification of cross sections subject to bending and axial force;
- An additional worked example of a beam-column with transversal loads and end moments;
- A new Annex containing formulas for common torsional cases;
- A revised and expanded Annex with formulas for elastic critical moment calculation.

The authors are indebted to Profs. E. Mirambell and K. Rasmussen for their thorough revision of the section on torsion.

**Luís Simões da Silva**

**Rui Simões**

**Helena Gervásio**

Coimbra, 2016

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## PREFACE 1<sup>st</sup> EDITION

The General rules and rules for buildings of part 1-1 of Eurocode 3 constitute the core of the code procedures for the design of steel structures. They contain the basic guidance for structural modeling and analysis of steel frameworks and the rules for the evaluation of the resistance of structural members and components subject to different loading conditions.

According to the objectives of the ECCS Eurocode Design Manuals, it is the objective of this book to provide mix of “light” theoretical background, explanation of the code prescriptions and detailed design examples. Consequently, this book is more than a manual: it provides an all-in-one source for an explanation of the theoretical concepts behind the code and detailed design examples that try to reproduce real design situations instead of the usually simplified examples that are found in most textbooks.

This book evolved from the experience of teaching Steel Structures according to ENV 1993-1-1 since 1993. It further benefited from the participation in Technical Committees TC8 and TC10 of ECCS where the background and the applicability of the various clauses of EN 1993-1-1 was continuously questioned. This book covers exclusively part 1-1 of Eurocode 3 because of the required level of detail. Forthcoming volumes discuss and apply most of the additional parts of Eurocode 3 using a consistent format.

Chapter 1 introduces general aspects such as the basis of design, material properties and geometric characteristics and tolerances, corresponding to chapters 1 to 4 and chapter 7 of EN 1993-1-1. It highlights the important topics that are required in the design of steel structures. Structural analysis is discussed in chapter 2, including structural modelling, global analysis and classification of cross sections, covering chapter 5 of EN 1993-1-1. The design of steel members subjected to various types of internal force (tension, bending and shear, compression and torsion) and their combinations is described in chapter 3, corresponding to chapter 6 of EN 1993-1-1. Chapter 4 presents the design of steel structures using 3D elastic analysis based on the case study of a



## PREFACE

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real building. Finally, chapter 5 discusses plastic design, using a pitched-roof industrial building to exemplify all relevant aspects.

Furthermore, the design examples provided in this book are chosen from real design cases. Two complete design examples are presented: i) a braced steel-framed building; and ii) a pitched-roof industrial building. The chosen design approach tries to reproduce, as much as possible, real design practice instead of more academic approaches that often only deal with parts of the design process. This means that the design examples start by quantifying the actions. They then progress in a detailed step-by-step manner to global analysis and individual member verifications. The design tools currently available and adopted in most design offices are based on software for 3D analysis. Consequently, the design example for multi-storey buildings is analysed as a 3D structure, all subsequent checks being consistent with this approach. This is by no means a straightforward implementation, since most global stability verifications were developed and validated for 2D structures.

The authors are indebted to Prof. Reidar Bjorhovde who carried out a detailed technical review of the manuscript and provided many valuable comments and suggestions. Warm thanks to Prof. David Anderson who carried out an additional detailed revision of the book and also made sure that the English language was properly used. Further thanks to Liliana Marques and José Alexandre Henriques, PhD students at the University of Coimbra, for the help with the design examples of chapter 4. Additional thanks to Prof. Tiago Abecasis who spotted innumerable “bugs” in the text. Finally, thanks to Filipe Dias and the staff of cmm and ECCS for all the editorial and typesetting work, making it possible to bring to an end two years of work in this project.

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xviii

**Luís Simões da Silva**

**Rui Simões**

**Helena Gervásio**

Coimbra, 2010

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# TABLE OF CONTENTS

<b>FOREWORD</b>	xiii
<b>PREFACE</b>	xv
<b>Chapter 1</b>	
<b>INTRODUCTION</b>	<b>1</b>
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 <sup>nd</sup> order analysis	86
2.3.3. Imperfections	88
2.3.4. Worked example	94
2.4. Classification of Cross Sections	108

---

**Chapter 3**

<b>DESIGN OF MEMBERS</b>	<b>119</b>
3.1. Introduction	119
3.1.1. General	119
3.1.2. Resistance of cross sections	120
3.1.2.1. <i>General criteria</i>	120
3.1.2.2. <i>Section properties</i>	121
3.1.3. Buckling resistance of members	125
3.2. Tension	125
3.2.1. Behaviour in tension	125
3.2.2. Design for tensile force	128
3.2.3. Worked examples	131
3.3. Laterally Restrained Beams	138
3.3.1. Introduction	138
3.3.2. Design for bending	139
3.3.2.1. <i>Elastic and plastic bending moment resistance</i>	139
3.3.2.2. <i>Uniaxial bending</i>	141
3.3.2.3. <i>Bi-axial bending</i>	142
3.3.2.4. <i>Net area in bending</i>	142
3.3.3. Design for shear	143
3.3.4. Design for combined shear and bending	144
3.3.5. Worked examples	146
3.4. Torsion	157
3.4.1. Theoretical background	157
3.4.1.1. <i>Introduction</i>	157
3.4.1.2. <i>Uniform torsion</i>	159
3.4.1.3. <i>Non-uniform torsion</i>	161

---

**TABLE OF CONTENTS**

---

3.4.1.4. <i>Cross section resistance in torsion</i>	166
3.4.2. Design for torsion	173
3.4.3. Worked examples	176
3.5. Compression	186
3.5.1. Theoretical background	186
3.5.1.1. <i>Introduction</i>	186
3.5.1.2. <i>Elastic critical load</i>	186
3.5.1.3. <i>Effect of imperfections and plasticity</i>	192
3.5.2. Design for compression	198
3.5.3. Worked examples	204
3.6. Laterally Unrestrained Beams	212
3.6.1. Introduction	212
3.6.2. Lateral-torsional buckling	212
3.6.2.1. <i>Introduction</i>	212
3.6.2.2. <i>Elastic critical moment</i>	213
3.6.2.3. <i>Effect of imperfections and plasticity</i>	223
3.6.3. Lateral-torsional buckling resistance	225
3.6.4. Worked examples	229
3.7. Beam-Columns	242
3.7.1. Introduction	242
3.7.2. Classification of cross sections under bending and axial force	243
3.7.3. Cross section resistance	247
3.7.3.1. <i>Theoretical background</i>	247
3.7.3.2. <i>Design resistance</i>	249
3.7.4. Buckling resistance	253
3.7.4.1. <i>Theoretical background</i>	253
3.7.4.2. <i>Design resistance</i>	256
3.7.5. Worked examples	265

---

## Chapter 4

<b>ELASTIC DESIGN OF STEEL STRUCTURES</b>	<b>293</b>
4.1. Introduction	293
4.2. Simplified Methods of Analysis	295
4.2.1. Introduction	295
4.2.2. Amplified sway-moment method	297
4.2.3. Sway-mode buckling length method	299
4.2.4. Worked example	300
4.3. Member Stability of Non-prismatic Members and Components	310
4.3.1. Introduction	310
4.3.2. Non-prismatic members	310
4.3.3. Members with intermediate restraints	316
4.3.4. General method	322
4.3.5. Worked example	325
4.4. Design Example 1: Elastic Design of Braced Steel-Framed Building	340
4.4.1. Introduction	340
4.4.2. Description of the structure	342
4.4.3. General safety criteria, actions and combinations of actions	344
4.4.3.1. <i>General safety criteria</i>	344
4.4.3.2. <i>Permanent actions</i>	345
4.4.3.3. <i>Imposed loads</i>	345
4.4.3.4. <i>Wind actions</i>	346
4.4.3.5. <i>Summary of basic actions</i>	353
4.4.3.6. <i>Frame imperfections</i>	353
4.4.3.7. <i>Load combinations</i>	356
4.4.3.8. <i>Load arrangement</i>	358
4.4.4. Structural analysis	359

TABLE OF CONTENTS

---

4.4.4.1. <i>Structural model</i>	359
4.4.4.2. <i>Linear elastic analysis</i>	360
4.4.4.3. <i>Susceptibility to 2<sup>nd</sup> order effects: elastic critical loads</i>	361
4.4.4.4. <i>2<sup>nd</sup> order elastic analysis</i>	362
4.4.5. <i>Design checks</i>	363
4.4.5.1. <i>General considerations</i>	363
4.4.5.2. <i>Cross section resistance</i>	365
4.4.5.3. <i>Buckling resistance of beams</i>	366
4.4.5.4. <i>Buckling resistance of columns and beam-columns</i>	366
<b>Chapter 5</b>	
<b>PLASTIC DESIGN OF STEEL STRUCTURES</b>	<b>367</b>
5.1. <i>General Principles for Plastic Design</i>	367
5.1.1. <i>Introduction</i>	367
5.1.2. <i>Plastic limit analysis: method of mechanisms</i>	368
5.1.3. <i>Code requirements for plastic analysis</i>	372
5.2. <i>Methods of Analysis</i>	376
5.2.1. <i>Introduction</i>	376
5.2.2. <i>Approximate methods for pre-design</i>	376
5.2.3. <i>Computational analysis</i>	388
5.2.4. <i>2<sup>nd</sup> order effects</i>	393
5.2.4.1. <i>Introduction</i>	393
5.2.4.2. <i>Elastic critical load</i>	394
5.2.4.3. <i>2<sup>nd</sup> order computational analysis</i>	397
5.2.4.4. <i>Simplified methods for analysis</i>	397
5.2.5. <i>Worked example</i>	400
5.3. <i>Member Stability and Buckling Resistance</i>	410

---

---

5.3.1. Introduction	410
5.3.2. General criteria for the verification of the stability of members with plastic hinges	410
5.3.3. Bracings	411
5.3.4. Verification of the stability of members with plastic hinges	414
5.3.4.1. <i>Introduction</i>	414
5.3.4.2. <i>Prismatic members constituted by hot-rolled or equivalent welded I sections</i>	415
5.3.4.3. <i>Haunched or tapered members made of rolled or equivalent welded I sections</i>	417
5.3.4.4. <i>Modification factors for moment gradients in members laterally restrained along the tension flange</i>	420
5.3.5. Worked examples	423
5.4. Design Example 2: Plastic Design of Industrial Building	432
5.4.1. Introduction	432
5.4.2. General description	433
5.4.3. Quantification of actions, load combinations and general safety criteria	434
5.4.3.1. <i>General criteria</i>	434
5.4.3.2. <i>Permanent actions</i>	434
5.4.3.3. <i>Imposed loads</i>	434
5.4.3.4. <i>Snow loads</i>	435
5.4.3.5. <i>Wind loads</i>	435
5.4.3.6. <i>Summary of basic actions</i>	440
5.4.3.7. <i>Imperfections</i>	440
5.4.3.8. <i>Load combinations</i>	441
5.4.4. Pre-design	443
5.4.5. Structural analysis	446

---



## TABLE OF CONTENTS

5.4.5.1. <i>Linear elastic analysis</i>	446
5.4.5.2. <i>2<sup>nd</sup> order effects</i>	448
5.4.5.3. <i>Elastic-plastic analysis</i>	449
5.4.6. Code checks	451
5.4.6.1. <i>General considerations</i>	451
5.4.6.2. <i>Cross section resistance</i>	451
5.4.6.3. <i>Buckling resistance of the rafters</i>	451
5.4.6.4. <i>Buckling resistance of the columns</i>	454
5.4.7. Synthesis	454
<b>REFERENCES</b>	<b>455</b>
<b>Annex A</b>	
<b>FORMULAS FOR COMMON TORSIONAL CASES</b>	<b>465</b>
A.1. Cross Sectional Properties for Torsion	465
A.2. Solution of Differential Equation for Torsion	467
A.2.1 Concentrated torsional moment	467
A.2.2 Distributed torsional moment	474
<b>Annex B</b>	
<b>ELASTIC CRITICAL MOMENT</b>	<b>483</b>
B.1. Abacus to Calculate the Coefficients $C_1$ , $C_2$ and $C_3$	483
B.1.1 Elastic critical moment in beams submitted to end moments simultaneously with transverse loads	483
B.1.2 Elastic critical moment of unbraced cantilevers	487
B.2. Alternative Equations for the Determination of the Elastic Critical Moment	490