Design of Steel Structures for Buildings in Seismic Areas

Eurocode 8: Design of Structures for Earthquake Resistance
Part 1: General Rules, Seismic Action and Rules for Buildings

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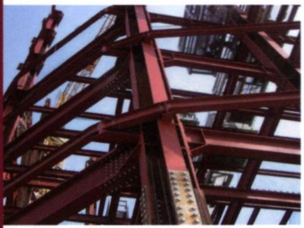

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The book deals with the seismic design of steel structures based on EN 1998-1 (2004). It contains the essentials of theoretical background of seismic engineering, design requirements and detailing rules for building applications. Calculation examples are included in the relevant chapters in order to provide a better understanding to the Reader. In addition, the book provides insights about the design assisted by testing as well as some design examples of real buildings: Tower Centre International, in Bucharest, awarded in 2007 with the ECCS Steel Design Award, a low-rise industrial building in Romania and the seismic design of the Fire Station in Naples, awarded in 1986 with the ECCS Steel Design Award.

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Part 1-1 – General rules and rules for buildings

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FOREWORD

There are many seismic areas in Europe. As times goes by, regional seismicity is better known and the number of places where earthquake is an action to consider in design increases. Of course, there are substantial differences in earthquake intensity between regions and the concern is much greater in many areas of Italy, for instance, than in most places in Northern Europe. However, even in Northern Europe, for structures for which a greater level of safety is required, like Seveso industrial plants, hospitals and public safety facilities, seismic design can be the most requiring design condition.

Designing for earthquake has original features in comparison with design for classical loading like gravity, wind or snow. The reference event for Ultimate Limit State seismic design is rare enough for an allowance to permanent deformations and structural damages, as long as people's life is not endangered. This means that plastic deformations are allowed at ULS, so that the design target becomes a global plastic mechanism. To be safe, the latter requires many precautions, on global proportions of structures and on local detailing. The seismic design concepts are completely original in comparison to static design. Of course, designing for a totally elastic behaviour even under the strongest earthquake remains possible but, outside of low seismicity areas, this option is generally left aside because of its cost.

This book is developed with a constant reference to Eurocode 8 or EN 1998-1:2004; it follows the organization of that code and provides detailed explanations in support of its rather dry expression. Of course, there are many other seismic design codes, but it must be stressed that there is nowadays a strong common thinking on the principles and the application rules in seismic design so that this book is also a support for the understanding of other continents codes.

Chapter 1 explains the principles of seismic design and their evolution throughout time, in particular the meaning, goals and conditions set forward by capacity design of structures and their components, a fundamental aspect of seismic design.

Chapter 2 explains the general aspects of seismic design: seismic actions, design parameters related to the shape of buildings, models for the analysis, safety verifications. Methods of analysis are explained in an exhaustive way: theoretical background, justifications of limits and factors introduced by the code, interest and drawbacks of each method, together with occasionally some tricks to facilitate model making and combination of load cases.

Chapter 3 focuses on design provisions specific to steel structures: ductility classes, requirements on steel material, structural typologies and design conditions related to each of them; an original insight on design for reparability is also included.

Chapter 4 provides an overview about the best practice to implement the requirements and design rules for ductile details, particularly for connections in moment resisting frames (MRF), concentrically braced frames (CBF) and eccentrically braced frames (EBF), and for other structural components like diaphragms.

Chapter 5 describes the guidance provided for design assisted by testing by EN 1990 and the specific rules for tests, a necessary tool for evaluating the performance characteristics of structural typologies and components in the plastic field and in cyclic/dynamic conditions.

Chapter 6 illustrates and discusses the design steps and verifications required by EN 1998-1 for a multi-storey Moment Resisting Frame.

Chapter 7 and 8 do the same respectively for buildings with CBF's and EBF's.

Chapter 9 presents three very different examples of real buildings erected in high seismicity regions: one tall building, one industrial hall and one design using base isolation. These examples are complete in the sense that they show the total design, where seismic aspects are only one part of the problem. These examples are concrete, because they illustrate practical difficulties of the real world with materials, execution, positioning…

The concepts, design procedures and detailing in seismic design may seem complex. This publication explains the background behind the rules, which clarify their objectives. Details on the design of the different building typologies are given, with reference to international practice and to recent research results. Finally, design examples and real case studies set out the design process in a logical manner, giving practical and helpful advice.

This book will serve the structural engineering community in expanding the understanding and application of seismic design rules, and, in that way, constitute a precious tool for our societies safety.

André Plumier
Honorary Professor, University of Liege

PREFACE

This manual aims to provide its readers with the background and the explanation of the main aspects dealing with the seismic design of steel structures in Europe. Therefore, the book focuses on EN 1998-1 (usually named part 1 of Eurocode 8 or EC8-1) that is the Eurocode providing design rules and requirements for seismic design of building structures. After 10 years from its final issue, both the recent scientific findings and the design experience carried out in Europe highlight some criticisms. In the light of such considerations, this book complements the explanation of the EC8-1 provisions with the recent research findings, the requirements of renowned and updated international seismic codes (e.g. North American codes and design guidelines) as well as the design experience of the Authors. Although the manual is oriented to EC8-1, the book aims to clarify the scientific outcomes, the engineering and technological aspects rather than sticking to an aseptic explanation of each clause of the EC8-1. Indeed, as shown in Chapter 4, the proper detailing of steel structures is crucial to guarantee adequate ductility of seismic resistant structures and the current codes does not give exhaustive guidelines to design ductile details since it only provides the fundamental principles. In addition, the practice of earthquake engineering significantly varies between European regions, reflecting the different layouts of each national seismic code as well as the level of knowledge and confidence with steel structures of each country. With this regard, a large number of European engineers believe that steel structures can withstand severe earthquakes without requiring special details and specifications as conversely compulsory for other structural materials like reinforced concrete and masonry. This belief direct results from the mechanical features of the structural steel, which is a high performance material, being stronger than concrete but lighter (if comparing the weight of structural members) and also very ductile and capable of dissipating large amounts of energy through yielding when subjected to cyclic inelastic deformations. However, although the material behaviour is important, the ductility of steel alone is not enough to guarantee ductile structural response. Indeed, as demonstrated by severe past earthquakes (e.g. Northridge 1994, Kobe 1995 and Christchurch 2011) there are several aspects ensuring good seismic behaviour of steel structures, which are related to (i) the conceptual design of the structure, (ii) the overall sizing of the member, (iii) the local detailing and (iv) proper technological requirements as well as ensuring that the structures are actually constructed as designed.

Therefore, this book primarily attempts to clarify all these issues (from Chapter 1 to 4) for European practising engineers, working in consultancy firms and construction companies. In addition, the examples of real buildings (see Chapter 9) are an added value, highlighting practical and real difficulties related to both design and execution.

This design manual is also meant as a recommended textbook for several existing courses given by the Structural Sections of Civil Engineering and Architectural Engineering Departments. In particular, this manual is oriented to advanced students (i.e. those attending MSc programmes) thanks to the presence of various calculation examples (see Chapter 6, 7 and 8) that simplify and speed up the understanding and the learning of seismic design of EC8 compliant steel structures. In addition, research students (i.e. those attending PhD programmes) can find useful insights for their experimental research activities by reading Chapter 5, which provides some guidance and discussion on how performing experimental tests of structural typologies and components in cyclic pseudo-static and dynamic conditions.

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