# Limit States Design in Structural Steel

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# PREFACE

## Preface to Ninth Edition

The Ninth Edition of this text introduces the changes to the 2009 edition of CSA–S16 standard. The changes in CSA-S16 that have affected the content of this edition consist of: the addition of a new equivalent moment factor for the lateral torsional buckling capacity of beams with non-linear moment distributions; new block shear provisions; changes to the design of column base plates; changes to the design of steel-concrete composite beams; and various changes in connection design, related to the bearing resistance of bolts, the resistance of welded joints with welds in more than one orientation within the same shear plane.

The first two chapters of the book deal with the interrelationship of design and analysis, various aspects of steel construction, the structural steels and sections available, the International System of Units, and the philosophy of the limit states design approach. With the 2005 edition of the National Building Code, the factored loads in the limit states design approach have been redefined, with the implementation of a companion load approach. The design of tension members, presented in Chapter 3, reflects changes to S16–09 with respect to failure by block shear in gusset plates and in coped beams. (This mode of failure was called tension and shear block failure in the earlier edition of the Standard.) The changes are meant to provide a more uniform approach for tension members of different shapes.

The design of columns presented in Chapter 4 has remained essentially the same as in the previous edition of the standard. A change in the designation of flange width for local buckling consideration was introduced for clarity and the design of column base plates now requires a minimum of four anchor rods. S16–09 has introduced a number of changes to the design of steel beams. Chapter 5 introduces the new definition of the equivalent moment factor for non-linear moment distribution. Chapters 6 and 7 go on to describe the design processes needed for particular kinds of beams—composite beams and plate girders. Changes to the magnitude of the compression stress block in the concrete portion of composite beams have been introduced in S16–09 for consistency with the reinforced concrete design standard, CSA–A23.3–04. The stability of members and frames has always been a difficult area for instructors to teach and for students to understand. Chapter 8 underwent significant changes in the Seventh and Eighth editions to integrate the analysis and design topics and to illustrate

these concepts for both single storey and multi-storey buildings. Clarifications have been introduced in this edition to distinguish between braced and unbraced frames, a concept that influences significantly the analysis and design process of beam-columns. Changes have been made in Chapter 9 to reflect changes in S16–09 with the bearing resistance of bolts and the strength calculation of welded joints where weld segments in different orientation are introduced in the same shear plane. The example design of framed building presented in Chapter 10 has been updated to reflect the changes in S16–09. Finally, Chapter 11 deals with fatigue. Although it is likely that most instructors will not be able to include it in the undergraduate teaching program, it should be useful as students begin their professional career and to practicing engineers who need to know more about this topic.

The intent of the authors still remains to provide a reference document for the training of those who will be responsible in the future for the design of steel structures. The book is intended primarily for a one or two term course in the subject at the undergraduate level. Consequently, some changes that were introduced in S16–09 that are related to topics usually covered at the graduate level (e.g. lateral torsional buckling of monosymmetric beams or of beams loaded at a point other than the shear centre) have not been presented in this book.

The authors acknowledge the contributions of the co-authors of previous editions of this book. These are Peter Adams, the principal co-author of technical material in editions through the Fifth, and Michael Gilmor and Hugh Krentz, responsible for industry-related material and who acted as Publishers through the Sixth Edition. Their contributions and influence continue in this edition.

The authors are indebted to friends and colleagues who have suggested improvements in wording and have identified errors in the earlier printing of this text. In particular, continuing support from Dr. Dominique Bauer from École de technologie supérieure and Mr. Charles Albert from CISC is gratefully acknowledged.

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# FOREWORD

For many years the CISC has supported the educational efforts of Canadian universities and other educational institutions by providing research grants, scholarships, films, slides, video tapes, computer programs, Handbooks, and other literature. As part of this continuing interest in education, the CISC is pleased to publish this textbook.

The Canadian Institute of Steel Construction does not assume responsibility for the contents of this book, nor for errors or oversights resulting from use of the information contained herein. All suggestions for improvement of this book will be forwarded to the authors for their consideration for future printings.

CISC is located at 3760 14th Avenue, Suite 200, Markham, Ontario, L3R 3T7. Contact can also be made as follows; telephone 905–946–0864, facsimile 905–946–8574, electronic mail *info@cisc-icca.ca*. A web site is also available: *www.cisc-icca.ca*.

The Eurocodes are a set of structural design standards, developed by CEN (European Committee for Standardisation) over the last 30 years, to cover the design of all types of structures in steel, concrete, timber, masonry and aluminium. In the UK, they are published by BSI under the designations BS EN 1990 to BS EN 1999; each of these ten Eurocodes is published in several Parts and each Part is accompanied by a National Annex that implements the CEN document and adds certain UK-specific provisions. Limit state design (LSD), also known as load and resistance factor design (LRFD), refers to a design method used in structural engineering. A limit state is a condition of a structure beyond which it no longer fulfills the relevant design criteria. The condition may refer to a degree of loading or other actions on the structure, while the criteria refer to structural integrity, fitness for use, durability or other design requirements. A structure designed by LSD is proportioned to sustain all actions