Steel Design Guide 28

Stability Design of Steel Buildings

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Preface

This Design Guide provides guidance in the application of the stability design provisions that were introduced in the 2005 AISC *Specification for Structural Steel Buildings* and the 13th Edition AISC *Steel Construction Manual*. Although some of the relevant section and equation numbers have changed in the 2010 AISC *Specification for Structural Steel Buildings* and the 14th Edition AISC *Steel Construction Manual*, the 2010 provisions for stability design are similar, being a refinement and simplification of the 2005 provisions. Thus, the guidance and recommendations given in this document apply equally to the 2010 AISC *Specification* and 14th Edition AISC *Manual.*

Although some jurisdictions in the United States are using a more current version of the *International Building Code*, the 2006 IBC is most common at the time of writing of this document. Because the 2006 IBC refers to the 2005 AISC *Specification*, those provisions are the basis of this document. To assist the reader, however, summaries are provided to highlight the refinements and simplifications made in the 2010 AISC *Specification* provisions. The changes for 2010 are indicated in "Update Notes" in shaded boxes analogous to the User Notes in the *Specification*; some of the changes in equation numbers and section references are indicated in bracketed statements in line with the text.

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Chapter 1
Introduction

1.1 PURPOSE OF THIS DESIGN GUIDE

With the 2005 AISC *Specification for Structural Steel Buildings* (AISC, 2005a), hereafter referred to as the AISC *Specification*, the state of the art was advanced to include three methods for stability design, including the introduction of a powerful new approach—the direct analysis method (DM). The DM is a practical alternative to the more traditional effective length method (ELM), which has been the basis of stability considerations in earlier editions of the AISC *Specification*, and continues to be permitted. In addition, the third method provided is a streamlined design procedure called the first-order analysis method (FOM), which is based upon the DM with a number of conservative simplifications.

The primary purpose of this Design Guide is to discuss the application of each of the aforementioned three methods and to introduce the DM to practicing engineers. The DM is permitted and referenced in Chapter C of the AISC *Specification*, and its procedural details are described in Appendix 7. As explained in Chapter C and in this Design Guide, the DM is required in cases where the second-order effects due to sidesway are significant.

Update Note: The stability provisions of the 2010 AISC *Specification* (AISC, 2010) are technically very similar to those in the 2005 edition. Where there are technical changes, they are in the direction of being less conservative: A structure that conforms to the 2005 AISC *Specification* could reasonably be expected to be in conformance with the stability requirements of the 2010 edition as well.

The provisions have, however, been substantially rearranged and reorganized for 2010 in the interest of greater transparency and clarity. The effects that must be considered in design for stability are spelled out and it is stated that any rational method that accounts for those effects, including the three prescribed methods, is permitted. The direct analysis method is presented in Chapter C as the primary method; the effective length and first-order analysis methods, and limitations on their use, are presented in Appendix 7. All three of the methods are identified explicitly by name (the ELM and FOM were not named in 2005).

Some of the attractive features of the DM include:

- There is no need to calculate K factors.
- The internal forces are represented more accurately at the ultimate limit state.
- The method applies in a logical and consistent manner for all types of steel frames, including braced frames, moment frames, and combined framing systems.

Other purposes of this Design Guide are as follows:

- Discuss the requirements for overall stability design in the 2005 AISC *Specification* as well as in the 2006 International Building Code (ICC, 2006) and the 2005 edition of ASCE/SEI 7, *Minimum Design Loads for Buildings and Other Structures* (ASCE, 2005), hereafter referred to as ASCE/SEI 7.
- Describe the traditional ELM and update designers on new conditions placed on its use.
- Introduce the new FOM and explain when this method can be advantageous.
- Discuss application of stability methods to seismic design.
- Highlight common pitfalls and errors in stability analysis and design.
- Provide an overview of basic principles of stability analysis and design for practical steel structures.
- Provide guidance on benchmarking of second-order analysis software.
- Illustrate how the DM can be applied to provide streamlined and efficient solutions for assessment of column stability bracing.

This Design Guide illustrates the application of the overall stability design requirements of the AISC *Specification* using representative examples taken from routine design office practice. Emphasis is placed on practical applications as opposed to theoretical derivations. The examples use wide-flange shapes predominantly for the members. However, the material presented can be applied to frames designed using other rolled shapes and hollow structural sections, as well as built-up sections.

This Design Guide does not address the specifics of the different methods of second-order frame analysis. An extensive list of references is provided for users needing additional background on the theoretical basis of the provisions. The *Guide to Stability Design Criteria for Metal Structures* (Ziemian, 2010) is referenced for detailed background and developments in a number of the primary and related topic areas.

1.2 HOW TO USE THIS DESIGN GUIDE

This guide describes and illustrates the application of the three methods of stability design contained in the AISC *Specification*. In addition, it addresses a number of other related topics important to the stability design of steel buildings, and provides references that will serve to give readers a more complete understanding.

Chapter 1 provides an overview and discussion of key general considerations. Chapters 2, 3 and 4 present each of the methods of stability analysis and design. Chapter 2 addresses the effective length method (ELM), Chapter 3 explains the direct analysis method (DM), and Chapter 4 discusses the first-order analysis method (FOM). Example analysis and design calculations are provided at the end of each of these chapters. Chapter 5 provides an overview of several important special topics pertinent to steel building stability design. Several appendices provide more detailed discussions.

This Design Guide can be used in a variety of ways as described in the following, depending on the reader's interests and intentions. For readers interested in quickly becoming proficient in performing stability design using any one of the three methods referenced in Chapter C of the AISC *Specification*:

1. Read Chapter 1 as an overview and proceed to Chapter 2 for the ELM, Chapter 3 for the DM, or Chapter 4 for the FOM.
2. Review the design examples worked for the desired method at the end of the corresponding chapter.
3. If seismic design is required, see Section 5.1, Application to Seismic Design.
4. See Appendix D for discussion of proper benchmarking of second-order analysis software.
5. Read Appendix C to learn about the modeling of out-of-plumbness in taller building structures when using the DM or ELM methods.
6. See Section 5.2 for discussion of common pitfalls in stability analysis and design.

It is not necessary to read all sections of this guide to immediately begin solving problems by any of the three methods. The overview chapter for each of the design methods and each of the corresponding design examples show all the steps required to solve a given problem.

For readers interested in an overview of stability design methods in general or in the theoretical background to any method should read Chapter 1 and Appendix A, followed by the chapter covering the specific method of interest and the various pertinent references. For guidance in benchmarking of second-order analysis programs, see Appendix D of this guide. For readers who want to learn about stability bracing design using second-order analysis, read Appendix 6 of the AISC *Specification* and Commentary and Appendix E of this design guide.

A summary of design recommendations is contained at the end of each chapter or major section where appropriate. This allows for a quick review of the salient points covered in the particular chapter or section.

1.3 OVERVIEW OF STABILITY ANALYSIS AND DESIGN METHODS

The 2006 *International Building Code* adopts various reference standards for the definition of load effects and requirements pertaining to specific construction materials. It references the ASCE/SEI 7 Standard, *Minimum Design Loads for Buildings and Other Structures*, for loading requirements, including dead, live, wind, seismic, snow and rain loads. For structural steel design, it references AISC standards, including ANSI/AISC 360-05, *Specification for Structural Steel Buildings* and ANSI/AISC 341-05, *Seismic Provisions for Structural Steel Buildings* (AISC, 2005c). Each of these documents contains requirements for stability and this Design Guide provides a synthesis of many of these requirements with an emphasis on the overall stability design of steel building frames.

Note that stability design provisions have been significantly updated in the 2005 AISC *Specification*. The design for overall frame stability is addressed in Chapter C, Stability Analysis and Design; Appendix 1, Inelastic Analysis and Design; Appendix 6, Stability Bracing for Columns and Beams; and Appendix 7, Direct Analysis Method. Design for stability of individual members and structural components is addressed in many of the other chapters throughout the AISC *Specification*.

Update Note: The 2010 AISC *Specification* defines "design" as the combination of analysis to determine the required strengths of components and the proportioning of components to have adequate available strength. To be consistent with this definition, Chapter C is now titled Design for Stability and Appendix 1 is titled Design by Inelastic Analysis. In addition, the direct analysis method is now in Chapter C, while Appendix 7, titled Alternative Methods of Design for Stability, presents the effective length method and the first-order analysis method.

Part 2 of the 13th Edition AISC *Steel Construction Manual* (AISC, 2005b), hereafter referred to as the AISC *Manual,* contains a brief discussion of requirements pertaining to overall frame stability, including a simplified application of the ELM. Table 2-1 in the AISC *Manual* summarizes the three available methods for stability analysis and design covered in the AISC *Specification* and this guide. An expanded form of this table is included here as Table 1-1 as a convenient reference for the designer.