

Stability MATTERS

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A new AISC publication offers guidance on the three options
for stability analysis and design.

WITH NEW DESIGN RESOURCES come new ways of doing things.

When the 2005 AISC *Specification for Structural Steel Buildings* was published, it offered three methods for stability design, including 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 primary basis of stability considerations in earlier editions of the AISC *Specification* and continues to be permitted. A streamlined design procedure called the first-order analysis method (FOM), which is based upon the DM with a number of conservative simplifications, was also introduced.

And now practicing engineers, students and teachers have a new resource for stability analysis and design of steel buildings that incorporates these three methods: Design Guide 28—*Stability Design of Steel Buildings*. While the guide was primarily written around the 2005 *Specification*, it includes notes throughout to explain simplifications and improvements that were incorporated into the stability design provisions in the 2010 *Specification*.



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The following is a brief outline of what is included in the guide:

- ▶ Chapter 1: Introduction
 - Purpose of the guide and how to use it
 - Overview of stability analysis and design methods
 - The concept of notional loads
- ▶ Chapter 2: Effective Length Method (ELM)
- ▶ Chapter 3: Direct Analysis Method (DM)
- ▶ Chapter 4: First-Order Analysis Method (FOM)
- ▶ Chapter 5: Related Topics
 - Application to seismic design
 - Common pitfalls and errors in stability analysis and design
- ▶ Appendix A: Basic Principles of Stability
- ▶ Appendix B: Development of the First-Order Analysis Method
- ▶ Appendix C: Modeling Out-of-Plumbness for Taller Building Structures
- ▶ Appendix D: Practical Benchmarking and Application of Second-Order Analysis Software
- ▶ Appendix E: Bracing Requirements for Columns and Frames Using Second-Order Analysis
 - Types of column bracing
 - A summary of design recommendations for stability bracing problems using the new DM
 - Solution to practical column and frame bracing problems found in practice

Analyzing Analysis Methods

The primary purposes of the new guide are to discuss the application of each of the above three methods and to introduce the DM to practicing engineers. Some of the most attractive features of the new DM are that there is no need to calculate K factors; internal forces are represented more accurately at the ultimate limit state; and it applies in a logical and consistent manner for all types of steel frames, including braced frames, moment frames and combined framing systems.

The concept of notional loads is also presented—including the role these loads play in the DM—as is the concept of

stiffness reduction at the ultimate load state due to residual stresses in members and other effects. Since stability is an inherently nonlinear problem, the guide explains why all second-order analyses must be carried out at the ultimate strength load level, even when the allowable stress design method is used. In addition, many of the provisions contained in Chapter C of the 2010 *Specification* (Design for Stability) are explained in detail.

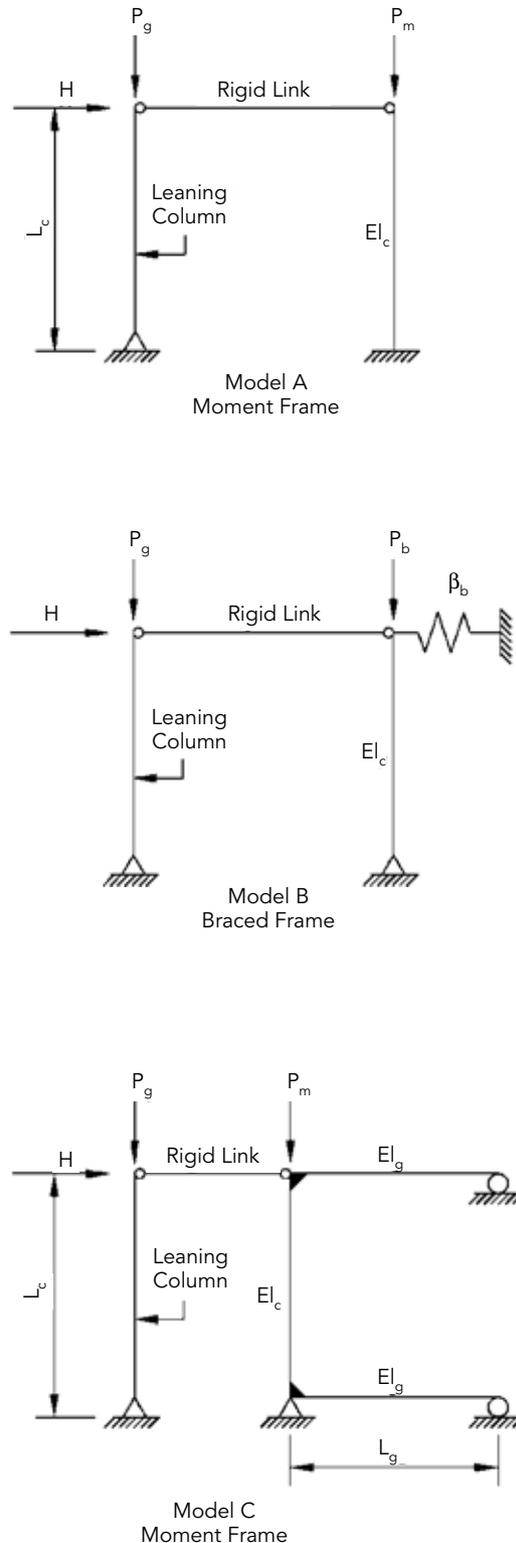
Practical design office problems are presented as well, demonstrating the use of each of the three methods and comparing the answers solved by each method for the same problem. The DM is permitted and now explicitly referenced in Chapter C of the 2010 *Specification*, and its procedural details are further described in Chapter C Commentary. As explained in Chapter C and in the new guide, the DM is required as the only acceptable method in cases where the second-order effects due to sidesway are significant. Appendix 7 of the 2010 *Specification* (Alternate Methods of Design for Stability) contains the ELM and the FOM approaches, and each has its own dedicated chapter, with example problems, in the new guide.

In addition to covering the three stability methods and emphasizing the DM, the guide does several other things as well, including:

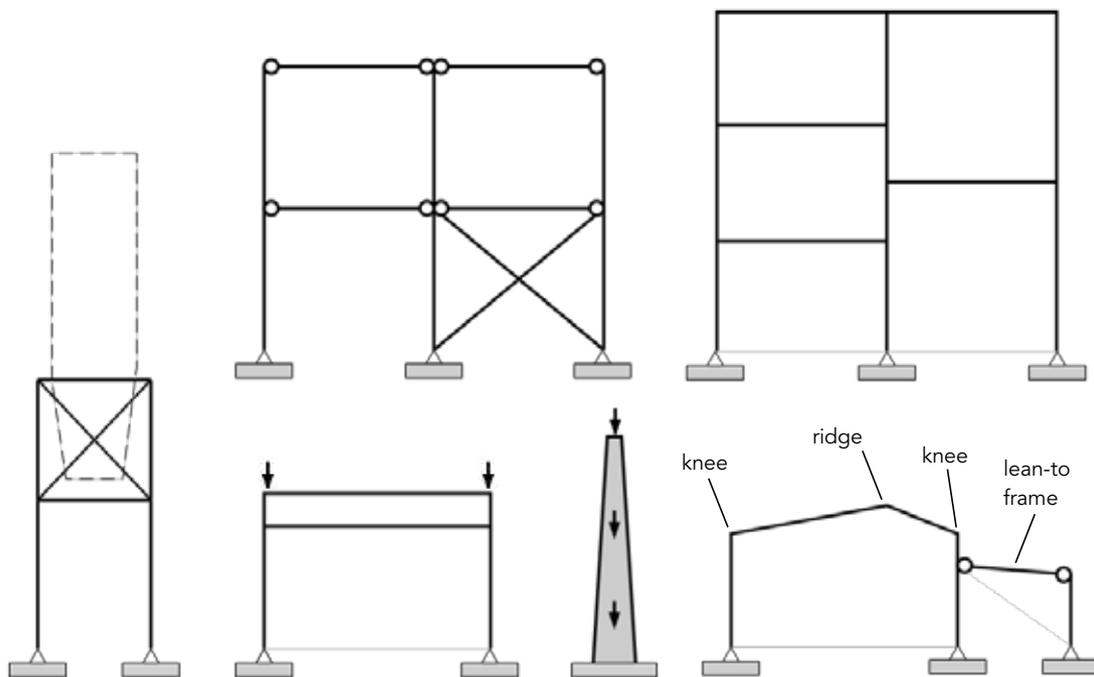
- ▶ Discussing the requirements for overall stability design in the 2005 and 2010 *Specifications*, as well as in the International Building Code and ASCE/SEI 7—*Minimum Design Loads for Buildings and Other Structures*
- ▶ Describing the traditional ELM and updating designers on new conditions placed on its use
- ▶ Introducing the FOM and explaining when this method can be advantageous
- ▶ Discussing application of stability methods to seismic design
- ▶ Highlighting common pitfalls and errors in stability analysis and design
- ▶ Providing an overview of basic principles of stability analysis and design for practical steel structures
- ▶ Providing guidance on benchmarking of second-order analysis software
- ▶ Illustrating how the DM can be applied to provide streamlined and efficient solutions for the assessment of column stability bracing

Applicable Appendices

Appendix A of the new guide contains practical tips about the different aspects of stability of steel structures. It begins with a definition of stability and describes factors that influence frame stability, such as second-order effects, geometric imperfections and fabrication/erection tolerances. Three simple stability models (see Figure 1) are described in detail and help illustrate many of the practical aspects of stability encountered in everyday practice, such as $P-\Delta$ and $P-\delta$ effects and when each should be considered; the effect of out-of-plumbness and how to account for it; and the effect of leaning columns on stability and second-order effects. In addition, an extensive discussion about the often perplexing effective length factor, K , is included for those designers accustomed to the ELM approach; many designers struggle with how to determine the effective length factor K for some of the more



▲ Figure 1. Simple models demonstrating various principles of stability.



▲ Figure 2. Finding the effective length factor K can be complicated.

common but complicated cases found in practice (see Figure 2). One of the most compelling reasons for using the new DM approach, as stated earlier, is that the method uses an effective length factor $K=1$.

Additionally, a section on the beam-column interaction equations found in Chapter H of the *Specification* is included in Appendix A, as is a discussion on out-of-plumbness effects.

For designers considering new software programs that proclaim to account for second-order $P-\Delta$ and $P-\delta$ effects as required by the AISC *Specification*, Appendix D provides guidance on determining whether second-order effects are considered with sufficient accuracy to meet specification requirements as defined in Chapter C. Practical guidelines are also given to assist designers in accurately modeling for second-order effects given potential limitations in the software being evaluated, such as not directly modeling $P-\delta$ effects in members.

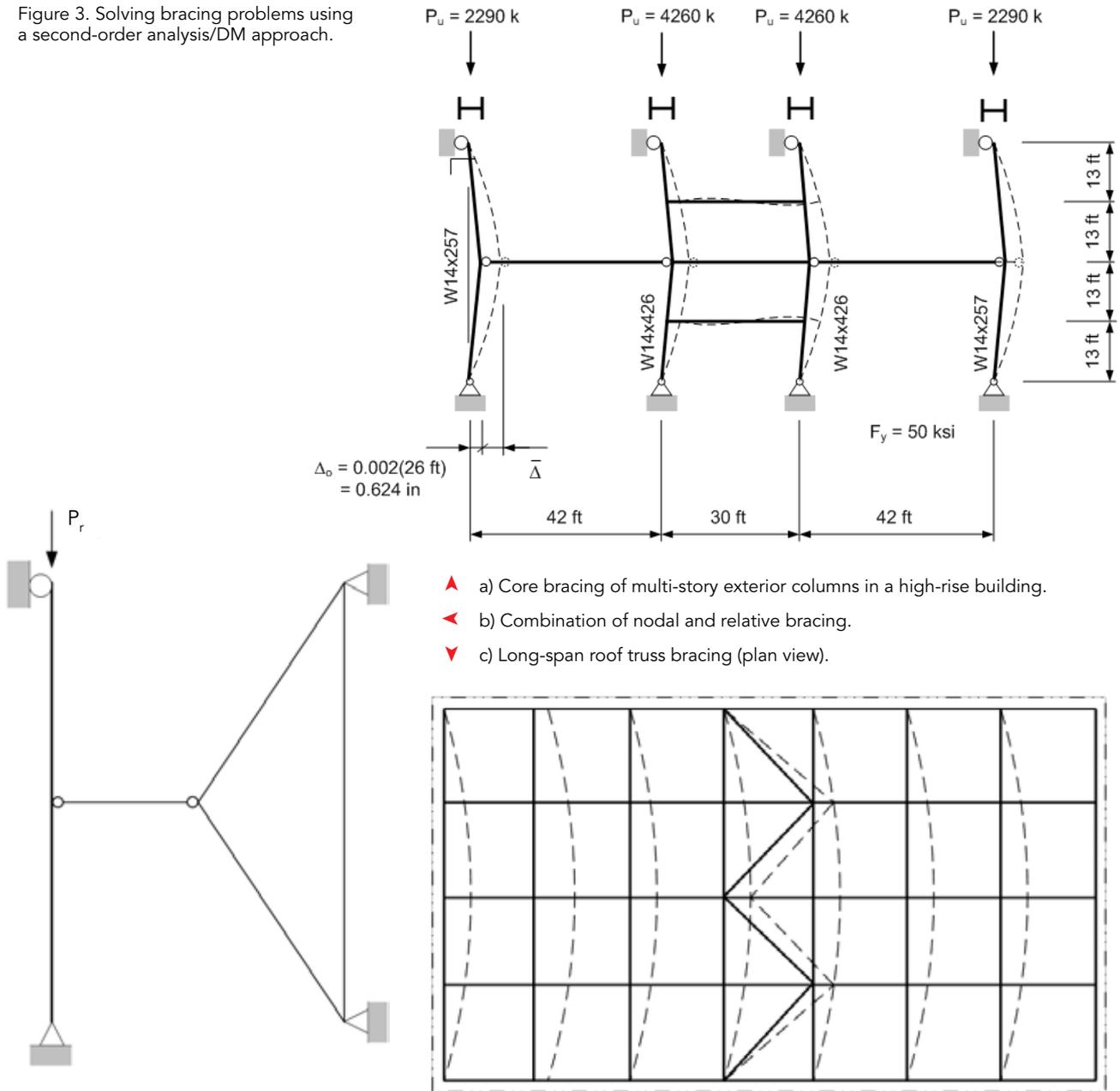
One of the new and potentially most useful topics covered in the guide is that of bracing requirements for columns and frames. While the *Specification's* Appendix 6—Stability Bracing for Columns and Beams provides relatively simple practical equations for beam and column bracing, many designers

struggle with determining the appropriate bracing classification (relative, nodal, lean-on or continuous) for their problem. The new guide's Appendix E—Bracing Requirements for Columns and Frames Using Second Order Analysis explains the various types of bracing and provides a detailed step-by-step approach to using a second-order analysis with the principles of the DM to solve perplexing and complex column bracing requirements. This approach is permitted in Appendix 6 of the *Specification* and is a powerful tool in solving complex bracing problems more accurately. (A few of the guide's sample bracing problems, which are solved using second-order analysis and DM, are shown in Figure 3, next page.)

Whether you seek to better understand your favorite method of stability design, are looking to understand basic principles of stability effects in steel building structures or simply want to learn how to use a second-order analysis approach for solving complex bracing problems, Design Guide 28 is a new powerful reference for your design office library. ■

AISC members can download Design Guide 28—Stability Design of Steel Buildings as a free PDF at www.aisc.org/epubs.

Figure 3. Solving bracing problems using a second-order analysis/DM approach.



- ▲ a) Core bracing of multi-story exterior columns in a high-rise building.
- ▲ b) Combination of nodal and relative bracing.
- ▲ c) Long-span roof truss bracing (plan view).