If you've ever asked yourself "Why?" about something related to structural steel design or construction, *Modern Steel Construction*'s monthly Steel Interchange column is for you! Send your questions or comments to **solutions@aisc.org**.

steel interchange

This month's Steel Interchange features questions and answers that followed the 2013 SteelDay webinar "The Life of the K-Factor" by Charlie Carter, AISC vice president and chief structural engineer. If you missed this webinar, you can view it at:
www.aisc.org/content.aspx?id=35624

All answers are from Carter and relate to Chapter C and Appendices 7 and 8 in the 2010 AISC *Specification*.

Question 1

How is the direct analysis method different than analyzing using the P-Δ/δ analysis?

Second-order analysis (for P-Δ and P-δ effects) is only one part of what is required for stability design. And, it is one part of the direct analysis method, just as it is one part of the effective length method.

Question 2

Is there any guidance available on how the direct analysis method should be applied when checking a structure for earthquake resistance?

There is a good explanation of this in a paper in the 3rd Quarter 2011 AISC *Engineering Journal*. It is titled "Design of Steel Buildings for Earthquake and Stability by Application of ASCE 7 and AISC 360," and it was written by Malley, Hooper and Nair. You can get that paper at **www.aisc.org/epubs** (and it's free to AISC members).

Question 3

How was the stiffness reduction factor of 0.8 used in the direct analysis method determined?

The coefficient 0.8 was selected based upon evaluation of what level of stiffness reduction produces an appropriate increase in the deformations of the framing to get the right force and moment amplification in the analysis. The factor τ_b also may apply and can further reduce stiffness.

Question 4

If lateral loading is the primary load on the structure, should the 0.2% notional loading be included?

If B_2 is not greater than 1.7 with reduced stiffnesses EA^* and EI^*, the notional loads are applied to gravity load combinations only. If this B2 is greater than 1.7, the notional loads are applied to all combinations. This is stated in Section C2.2b(4) in the 2010 AISC *Specification*. Note that in the 2005 AISC *Specification*, the dividing line was at 1.5 based upon EA and EI unreduced. These are essentially equivalent criteria.

Question 5

Can you explain how the factor τ_b can be set equal to 1.0 simply by increasing the notional load factor?

This is just a mathematical simplification. The studies that were done to calibrate the direct analysis method showed equivalence between the effect of reducing the stiffness by τ_b and increasing the $0.002Y_i$ notional load to $0.003\ Y_i$.

Question 6

Can the direct analysis method be used to design stepped columns?

Yes, I think this is a case where the direct analysis method is particularly helpful. The primary difficulty with a stepped column is the determination of K. So if you use direct analysis, you avoid that problem.

Question 7

When using the effective length method, can you provide a good reference/article that covers the recommended *K* factors (less than 1) for braces on a "heavy gusseted connection" frame?

If you mean for the gusset, the AISC *Manual* makes it clear that $K = 0.65$ is a good value to use for corner gussets. If instead you mean for the brace itself, we use $K = 1$ unless you go into greater detail to calculate a smaller K. Note, however, that if you do this, you have to ensure that the continuity you are assuming is reflected in the model. Dowswell has two papers in *Engineering Journal* related to this: "Effective Length Factors for Gusset Plate Buckling" and "Technical Note: Effective Length Factors for Gusset Plates in Chevron Braced Frames."

Question 8

If I continue to use the effective length method, are there adjustments to *K* for non prismatic (tapered cross section) columns?

Yes. In AISC Design Guide 25, tapered members are addressed directly. You can download this publication at **www.aisc.org/epubs** (free to AISC members).

Question 9

What about for cases in which we used to have *K* less than 1?

I assume you mean in a braced frame. If you use K less than 1, you are assuming continuity and then you have to consider that in your analysis. That may be more complicated than it's worth.

steel interchange

Question 10

So, is the point that the *K* factor in the AISC column equation should always be set equal to 1, now?

If you use the direct analysis method, yes, *K* can be taken as 1 always. This is not generally true for the effective length method, though there are conditions for stiff structures that also permit the simple use of *K*=1 in that method as well. For the first-order analysis method, *K* can be taken equal to 1 in all cases.

Question 11

What is the definition of a *leaning column*?

Long ago, we used to have all connections of beams and columns connected with moment connections. Modern frames often have only parts of the framing moment connected. The leaning columns are all the rest of the columns that are not part of the lateral framing. For a leaning (gravity-only) column, *K* is taken equal to 1. However, the gravity-only framing that leans on a moment frame affects the *K* of the columns in the moment frame when the Effective Length Method is used. The effect is captured in the forces and moments in the direct analysis method and first-order analysis method.

Question 12

In the AISC column equation the LRFD ϕ was changed from 0.85 to 0.9, and a corresponding reduction in Ω for ASD was used in the 2005 AISC *Specification*. How was this increase in strength justified?

AISC equations and provisions often cover multiple cases for simplicity and convenience, and this means that the lowest case controls the decisions made in writing the equation or provision. In this specific case, up until 2005 columns made from universal mill plates were included in the multiple cases covered and required a lower ϕ. However, in preparing the 2005 revisions we realized that these products are not used anymore and the higher ϕ/lower Ω resulted.

Question 13

What resources are available for learning more about the stability design methods in the 2005 and 2010 AISC *Specifications*?

There are a number of presentations that have been given at NASCC: The Steel Conference. All sessions from recent past years are available online at **www.aisc.org/epubs** (look under "conference proceedings"). In print, there are two resources: AISC Design Guide 28 *Stability Design of Steel Buildings* by Griffis and White and "A Comparison of Frame Stability Analysis Methods in ANSI/AISC 360-05" in the 3rd Qtr. 2008 AISC *Engineering Journal* by Carter and Geschwindner. (These documents are available as free downloads to members at **www.aisc.org/epubs**.)

Question 14

Is there a way to avoid doing a second-order analysis?

Yes, you could use the first-order analysis method. Also, you could make your frame stiff enough that you could decide that second-order effects are negligible.

Question 15

Why is the factor 1.6 used to amplify the loads for ASD stability analysis instead of 1.5? The calibration point for LRFD and ASD is 1.5.

The goal is to get the right deformations, which produces an acceptable set of forces and moments for the resulting design. The factor 1.6, not 1.5, is used because second-order effects are not linear. In the judgment of the responsible committee, the nonlinearity is properly represented by the use of 1.6 instead of 1.5.

Question 16

I have heard that most software programs include P-Δ effects but ignore P-δ effects. How can I tell? And if my software does not address P-δ effects, how can I proceed when they are significant?

The Commentary to the AISC *Specification* provides benchmark problems (see the Chapter C Commentary in the 2010 AISC *Specification*) with known solutions. If you model these problems in your software, you can compare the results and see what is being done and what is not.

If you find that P-δ effects are not being considered, you can add nodes along the length of the column in the model to "trick" the software into tracking deformations along the length of the column. Alternatively, you can amplify your results with B_1 as it is given in Appendix 8 of the 2010 AISC *Specification*.

The complete collection of Steel Interchange questions and answers is available online. Find questions and answers related to just about any topic by using our full-text search capability. Visit Steel Interchange online at **www.modernsteel.com**.

Steel Interchange is a forum to exchange useful and practical professional ideas and information on all phases of steel building and bridge construction. Opinions and suggestions are welcome on any subject covered in this magazine.

If you have a question or problem that your fellow readers might help you solve, please forward it to us. At the same time, feel free to respond to any of the questions that you have read here. Contact Steel Interchange via AISC's Steel Solutions Center:

One E. Wacker Dr., Ste. 700, Chicago, IL 60601, tel: 866.ASK.AISC, fax: 312.803.4709, **solutions@aisc.org**.

DISCLAIMER: The opinions expressed in Steel Interchange do not necessarily represent an official position of the American Institute of Steel Construction and have not been reviewed. It is recognized that the design of structures is within the scope and expertise of a competent licensed structural engineer, architect or other licensed professional for the application of principles to a particular structure.

Steel SolutionsCenter