# The *New* Math

When you're looking for a fast solution, the AISC Basic Design Values cards are just the ticket.

By Charles J. Carter, S.E., P.E.

How common it is today to hear complaints that codes become more and more complex—and costly. Users will find that the 2005 AISC *Specification for Structural Steel Buildings* departs from this trend on both accounts. Not only is the 2005 specification simplified, it is also available as a free download at **www.aisc.org**.

The 2005 AISC specification is easy to apply because complete guidance is provided in each section. Fans of engineering judgment will appreciate the User Notes in the *Specification*, which provide help on practicality and economy in application. And the 13th Edition AISC *Steel Construction Manual* will speed the design process with its familiar—and improved—design aids.

However, when you seek a fast solution that can be done on the back of an envelope, the AISC Basic Design Values cards are just the ticket. These cards contain only the steel design equations you'll use on a daily basis—all on the front and back of two 5 × 8″ cards. Steel design with these cards is as simple as it was in the "good old days" but still benefits from all that we've learned and changed over the years.

Based upon the 2005 specification, Basic Design Values summarize the design requirements for simplified analysis and design of all typical beams, columns, braces, tension members, and connections. The cards include design equations for W-shapes, S-shapes, channels, hollow structural sections (HSS), pipe, bolts, welds and connected parts—all in both ASD and LRFD.

In many cases the simplifications provided in the cards required no overly conservative assumptions. Some examples of this include the compression, tension, and shear design equations found on the cards. Even the comparatively complex task of addressing noncompact and slender cross-sections is simplified for rapid design in these cards.

In some cases, slightly conservative assumptions permit significant simplifications:

- **Using the shape factor times *S* in place of the plastic section modulus *Z*.** This trades a small amount of flexural strength for a comparatively significant reduction in the amount of design effort required.
- **A simplified method of analysis that allows the full consideration of second-order effects with a single multiplier applied to first-order analysis results.** In many cases, the framing stiffness will be sufficient to satisfy the conditions for which $K$ can even be taken as unity for the design of the columns in moment frames with this method. The user should note the limitations that are implicit in the formulation of the simplified method—and explicitly presented in the cards.

How can you get these cards? The best way is to attend the AISC seminar "Design Steel Your Way," coming to a city near you throughout 2006, as listed at **www.aisc.org/seminars**. (This seminar will make its debut at the 2006 NASCC: The Steel Conference. Go to **www.aisc.org/nascc** for details about how to register.) Seminar attendees will receive a set of the cards printed on heavy cardstock, with rounded corners and a coating applied for durability. The cards are also available as a free download at **www.aisc.org/2005spec** and on pages 47 through 50 of this month's issue of *MSC*.

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**W-Shapes** | ASTM A992, $F_y = 50$ ksi, $F_u = 65$ ksi
**S-Shapes** | ASTM A36, $F_y = 36$ ksi, $F_u = 58$ ksi
**C- and MC-Shapes** | ASTM A36, $F_y = 36$ ksi, $F_u = 58$ ksi

| CONDITION | | | ASD | LRFD | RELATED INFO |
|---|---|---|---|---|---|
| **Tension** | | | $0.6F_yA_g \le 0.5F_uA_e$ | $0.9F_yA_g \le 0.75F_uA_e$ | For $A_e$, see Equation D3-1. |
| **Bending** | Strong Axis | $L_b \le L_p$ | $0.66F_yS_x$ | $0.99F_yS_x$ | See Note 1. $L_p = 300 r_y / \sqrt{F_y}$ $L_r$ and strengths when $L_b > L_r$ are given in the AISC Manual. |
| | | $L_p < L_b \le L_r$ | Use linear interpolation between $L_p$ and $L_r$. | | |
| | | $L_b = L_r$ | $0.42F_yS_x$ | $0.63F_yS_x$ | |
| | Weak Axis | | $0.9F_yS_y$ | $1.35F_yS_y$ | |
| **Shear (in strong axis)** | | | $0.4F_yA_w$ | $0.6F_yA_w$ | See Note 2. |
| **Compression** | $Kl/r \le 800/\sqrt{F_y}$ | | $0.6F_yA_g \times 0.658^P$ | $0.9F_yA_g \times 0.658^P$ | $P = F_y(Kl/r)^2/286{,}000$ See Note 3. |
| | $Kl/r > 800/\sqrt{F_y}$ | | $150{,}000A_g/(Kl/r)^2$ | $226{,}000A_g/(Kl/r)^2$ | |

**Notes:**
1. Multiply equations given for $L_b \le L_p$ by value in parentheses for W14×90 (0.97), W12×65 (0.98), and W6×15 (0.95).
2. Multiply equations given by 0.9 for W44×230, W40×149, W36×135, W33×118, W30×90, W24×55, W16×26, W12×14 and all C- and MC-shapes. In weak axis, equations given can be adapted by using $A_w = 1.8b_ft_f$.
3. Not applicable to slender shapes. For slender shapes, use $QF_y$ in place of $F_y$, where $Q = Q_sQ_a$ from Section E7. For C- and MC-shapes, also check Section E4.

**Basic Design Values 1** 
Based upon simplifying assumptions and arbitrary limitations. Direct use of the 2005 AISC Specification may be less constrained and less conservative.

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**Bolts** | ASTM A325, $F_u = 120$ ksi or ASTM A490, $F_u = 150$ ksi
**Welds** | $F_{EXX} = 70$ ksi
**Connected Parts**



| CONDITION | | | ASD | LRFD | RELATED INFO |
|---|---|---|---|---|---|
| Bolts | **Tension** | | $0.38F_uA_b$ | $0.56F_uA_b$ | -- |
| | **Shear (N bolts, per shear plane)** | | $0.2F_uA_b$ | $0.3F_uA_b$ | Multiply by 1.25 for X bolts. |
| | **Slip Resistance (Class A, STD holes)** | | $0.14F_uA_b$ | $0.21F_uA_b$ | Per slip plane. See Note 1. |
| | **Bearing** | | $0.6F_uL_ct \le 1.2F_ud_bt$ | $0.9F_uL_ct \le 1.8F_ud_bt$ | See Note 2. |
| Welds | **Shear (all welds except CJP)** | | $0.3F_{EXX}A_w$ | $0.45F_{EXX}A_w$ | See Note 3. |
| | **PJP Groove Welds** | Tension | $0.32F_{EXX}A_w$ | $0.48F_{EXX}A_w$ | See Section J2.1a. |
| | | Compression | $0.48F_{EXX}A_w \le 0.6F_yA_{BM}$ | $0.72F_{EXX}A_w \le 0.9F_yA_{BM}$ | Joint not finished to bear. |
| | **CJP Groove Welds** | | Strength equal to base metal. | | -- |
| Connected Parts | **Tension** | | $0.6F_yA_g \le 0.5F_uA_e$ | $0.9F_yA_g \le 0.75F_uA_e$ | For $A_e$, see Equation D3-1. |
| | **Shear** | | $0.4F_yA_g \le 0.3F_uA_n$ | $0.6F_yA_g \le 0.45F_uA_n$ | -- |
| | **Block Shear** | | $0.3F_uA_{nv} + 0.5U_{bs}F_uA_{nt}$ | $0.45F_uA_{nv} + 0.75U_{bs}F_uA_{nt}$ | See Note 4. |
| | **Compression** | $Kl/r \le 25$ | $0.6F_yA$ | $0.9F_yA$ | -- |
| | | $Kl/r > 25$ | Same as for W-shapes with $A_g = A$. | | |

**Notes:**
1. Slip checked as a serviceability limit state using ASD load combinations for ASD, LRFD load combinations for LRFD. For Class B surfaces, multiply by 1.43. For OVS or SSL holes, multiply by 0.85. For LSL holes, multiply by 0.7.
2. For LSL holes parallel to the direction of load, multiply by 0.83.
3. For fillet welds, multiply by 1.5 for transverse loading (90-degree load angle). For other load angles, see Section J2.
4. For calculation purposes, $F_uA_{nv}$ cannot exceed $F_yA_{gv}$. $U_{bs} = 1$ for a uniform tension stress; 0.5 for non-uniform tension stress.

**HSS** | ASTM A500 grade B, Rectangular $F_y = 46$ ksi, $F_u = 58$ ksi , Round $F_y = 42$ ksi, $F_u = 58$ ksi

**Pipe** | ASTM A53 grade B, $F_y = 35$ ksi, $F_u = 60$ ksi

| CONDITION | | ASD | LRFD | RELATED INFO |
|---|---|---|---|---|
| **Tension** | | $0.6F_yA_g \le 0.5F_uA_e$ | $0.9F_yA_g \le 0.75F_uA_e$ | For $A_e$, see Equation D3-1. |
| **Bending** | Rectangular HSS | $0.66F_yS$ | $0.99F_yS$ | See Note 1. |
| | Round HSS, Pipe | $0.78F_yS$ | $1.17F_yS$ | See Note 2. |
| **Shear** | Rectangular HSS | $0.36F_yA_w$ | $0.54F_yA_w$ | See Note 3. |
| | Round HSS, Pipe | $0.18F_yA_g$ | $0.27F_yA_g$ | See Note 4. |
| **Compression** | $Kl/r \le 800/\sqrt{F_y}$ | $0.6F_yA_g \times 0.658^P$ | $0.9F_yA_g \times 0.658^P$ | See Note 5. |
| | $Kl/r > 800/\sqrt{F_y}$ | $150{,}000A_g/(Kl/r)^2$ | $226{,}000A_g/(Kl/r)^2$ | $P = F_y(Kl/r)^2/286{,}000$ |

**Notes:**

1. Not applicable if limit at right is exceeded (see Section F7).
2. Not applicable if $D/t > 2{,}030/F_y$. (see Section F8).
3. Not applicable if limit at right is exceeded (see Section G5).
4. Not applicable if $L_v/D > 75$ (see Section G6).
5. For rectangular HSS, if limit at right is exceeded, use $QF_y$ in place of $F_y$, where $Q = Q_a$ from Section E7.2. For round HSS and pipe with $D/t > 3{,}190/F_y$, use $QF_y$ in place of $F_y$, where $Q = Q_a$ from Section E7.2.

| Size Limits for Rectangular HSS, in.* | | Nominal Wall Thickness | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $^5/_8$ | $^1/_2$ | $^3/_8$ | $^5/_{16}$ | $^1/_4$ | $^3/_{16}$ | $^1/_8$ |
| **Bending** | Flange | 18 | 14 | 10 | 9 | 7 | 5 | $3^1/_2$ |
| | Web | 20 | 20 | 20 | 18 | 14 | 10 | 7 |
| **Shear** | | 20 | 20 | 20 | 18 | 14 | 10 | 7 |
| **Compression** | | 20 | 16 | 12 | 10 | 8 | 6 | 4 |

*Table only covers up to 64-in. periphery limit in ASTM A500.

**Basic Design Values 2** 

Based upon simplifying assumptions and arbitrary limitations. Direct use of the 2005 AISC Specification may be less constrained and less conservative.

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## Analysis and Design



### Simplified Method (see Note 1)

Step 1. Perform first-order analysis. Use 0.2% of total story gravity load as minimum lateral load in all load combinations.
Step 2. Establish the design story drift limit and determine the lateral load required to produce it.
Step 3. Determine the ratio of the total story gravity load to the lateral load determined in Step 2. For ASD, multiply by 1.6.
Step 4. Multiply first-order results by the tabular value. $K$=1, except for moment frames when the tabular value is greater than 1.1.

| Design Story Drift Limit | Ratio from Step 3 (times 1.6 for ASD, 1.0 for LRFD) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 5 | 10 | 20 | 30 | 40 | 50 | 60 | 80 | 100 | 120 |
| H/100 | 1 | 1.1 | 1.1 | 1.3 | 1.4 | | | | When ratio exceeds 1.5, simplified method requires a stiffer structure. | | |
| H/200 | 1 | 1 | 1.1 | 1.1 | 1.2 | 1.3 | 1.3 | 1.4 | | | |
| H/300 | 1 | 1 | 1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.3 | 1.4 | 1.5 | |
| H/400 | 1 | 1 | 1 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.3 | 1.3 | 1.4 |
| H/500 | 1 | 1 | 1 | 1 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.3 | 1.3 |

K=1

| Other Elastic Methods (for plastic design, see Appendix 1) | Effective Length | Forces and Moments | Limitations | Reference |
|---|---|---|---|---|
| **First-order analysis method** – second-order effects captured from effects of additional lateral load | $K$ = 1 for all frames (see Note 2) | From analysis | $\Delta_{2nd}/\Delta_{1st} \le 1.5$; Axial load limited | Section C2.2b |
| **Effective length method** – second-order analysis with 0.2% of total story gravity load as minimum lateral load in all load combinations (see Note 3) | $K$ = 1, except for moment frames with $\Delta_{2nd}/\Delta_{1st} > 1.1$ | From analysis (see Note 3) | $\Delta_{2nd}/\Delta_{1st} \le 1.5$ | Section C2.2a |
| **Direct analysis method** – second-order analysis with notional lateral load and reduced $EI$ and $AE$ (see Note 3) | $K$ = 1 for all frames | From analysis (see Note 3) | None | Appendix 7 |

**Notes:**

1. Derived from the effective length method, using the $B_1$-$B_2$ approximation with $B_1$ taken equal to $B_2$.
2. An additional amplification for member curvature effects is required for columns in moment frames.
3. The $B_1$-$B_2$ approximation (Section C2.1b) can be used to accomplish a second-order analysis within the limitation that $B_2 \le 1.5$. Also, $B_1$ and $B_2$ can be taken equal to the multiplier tabulated for the simplified method above.
4. $\Delta_{2nd}/\Delta_{1st}$ is the ratio of second-order drift to first-order drift, which is also represented by $B_2$.