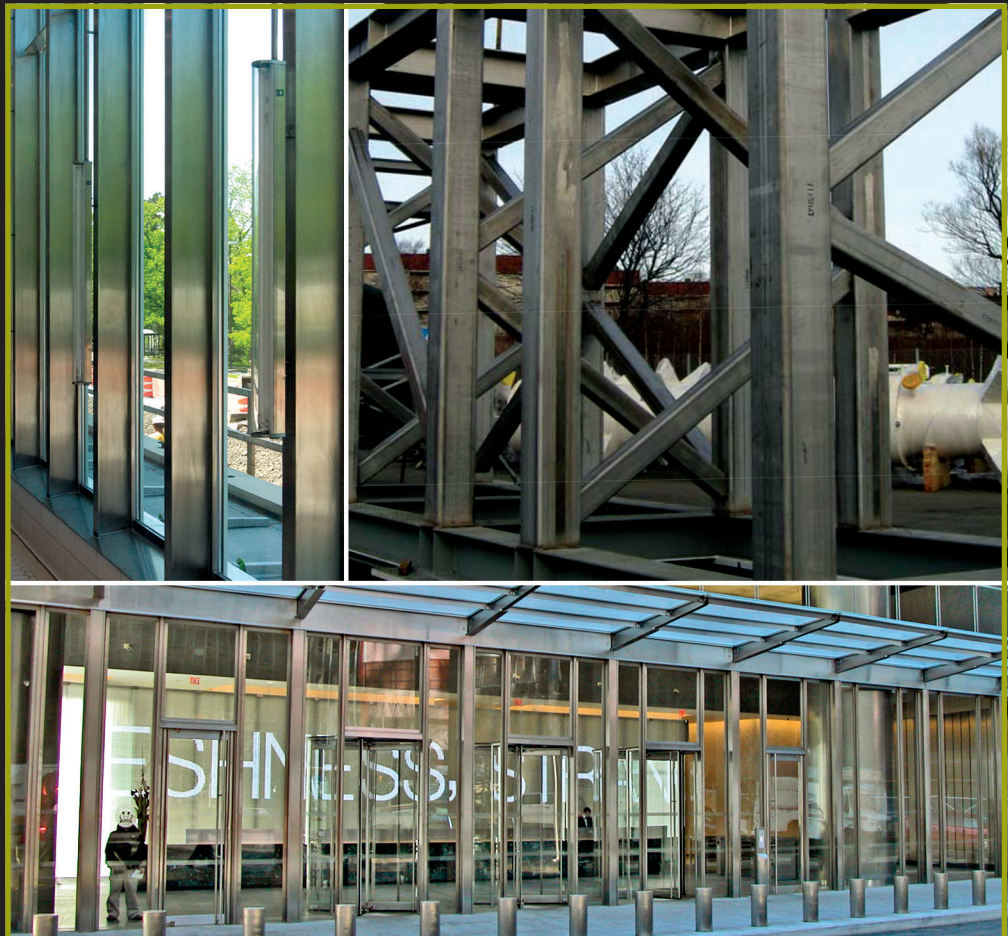


# STRUCTURAL STAINLESS STEEL DESIGN TABLES

IN ACCORDANCE WITH  
AISC DG27: STRUCTURAL STAINLESS STEEL





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# FOREWORD

This publication presents design data derived in accordance with AISC DG27 *Structural Stainless Steel* and presented in an equivalent set of tables to those in the *AISC Steel Construction Manual* for carbon steel sections.

The following structural sections are covered in this publication:

- W- and S-shapes
- C- and MC-shapes
- Equal angles
- Rectangular hollow structural sections (HSS)
- Square HSS
- Circular HSS.

Section ranges listed cover sections that are readily available at the time of printing.

The work was carried out by Nancy Baddoo and Michail Georgakis of The Steel Construction Institute.

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# GENERAL

## 1.1 Introduction

This publication presents design data in tabular formats as assistance to engineers who are designing stainless steel structural members in accordance with AISC Design Guide 27 *Structural Stainless Steel* (DG27)<sup>[1]</sup>. The guidance in DG27 is aligned with the design provisions in the 2010 AISC *Specification for Structural Steel Buildings* (AISC 360)<sup>[2]</sup>, hereafter referred to as the AISC *Specification*. The layout and contents of the tables covered in this report closely resemble those given for equivalent carbon steel structural sections in the AISC *Steel Construction Manual* <sup>[3]</sup>.

The symbols used are the same as those in DG27 (and the AISC *Specification*) or the referred product standards.

All properties and strengths have been accurately calculated and rounded to three significant figures.

Two strength levels are covered – 30 ksi which corresponds to austenitic stainless steels and 65 ksi which corresponds to duplex stainless steels. The initial modulus of elasticity was taken as 28,000 ksi (193,000 MPa) for the austenitic stainless steels and 29,000 ksi (200,000 MPa) for the duplex stainless steels (Table 2-9 of DG27).

The density used to calculate the nominal weight was taken as 500 lb/ft<sup>3</sup> (8000 kg/m<sup>3</sup>) (Table 2-9 of DG27).

The tables are divided into five parts:

- Part 1: Dimensions and Properties
- Part 2: Design of flexural members ( $F_y = 30$  ksi)
- Part 3: Design of flexural members ( $F_y = 65$  ksi)
- Part 4: Design of compression members ( $F_y = 30$  ksi)
- Part 5: Design of compression members ( $F_y = 65$  ksi)

The dimensions and property tables are applicable to sections of any grade of steel and have been calculated from the nominal geometry of the cross-sections. Footnotes to the tables give information on availability in duplex and austenitic grades.

The tables for flexural members give the maximum total uniform load for all the shapes except for angles, which are rarely used in bending.

The tables for compression give the available strength in axial compression for all the shapes except for S-, C- and MC-shapes which are rarely used as compression members.

No tables are given for strengths of hot rolled sections with  $F_y = 65$  ksi because they are not available.

Linear interpolation between the tabulated values is permitted.

Note that it is not necessary to give any table for members subject to combined loading because the main parameters required in these checks may be found in the strut (compression) and the beam (flexural) tables.

The tables for welded sections apply to sections which are continuously welded using full penetration butt welds. If intermittent welding, fillet welding or partial penetration welding is used, the designer should check that the shear resistance of the welded section is sufficient to carry the design shear loads. Intermittent welding should be avoided in environments with demanding corrosion/hygiene requirements. Care is also needed with the use of partial penetration welds in demanding corrosion/hygiene environments since corrosion may initiate at crevices.

## 1.2 Ranges of section sizes

At present, there is no specification on section sizes of stainless steel sections for structural applications. Consequently, a wide variety of sizes and shapes is used in practice. In order to provide practical design information, a large number of stockholders, fabricators and manufacturers in the US were contacted during the preparation of this publication in order to establish the most commonly used sizes for various section shapes. Based on the collected information, ranges of section sizes for stainless steel sections presented in this publication were established according to practical sizes in typical use, structural economy and effective use of material. Some of the shapes listed are not commonly produced or stocked. They will only be produced to order, and may be subject to minimum order quantities. Sections are far more widely available in austenitic stainless steel than duplex stainless steel.

Only the Standard weight class of pipe are covered. For structural applications, round HSS are a more economical choice than pipe.

## 1.3 Material, section dimensions and tolerances

The relevant product standards are as follows:

ASTM A240/ A240M Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications

*Chemical composition and mechanical properties for plate, sheet and strip*

ASTM A554: Standard Specification for Welded Stainless Steel Mechanical Tubing  
*Chemical composition, dimensional, straightness and other tolerances for round, square, and rectangular austenitic, ferritic and duplex stainless steel tubing. [This is the most commonly used standard for hollow structural applications. It covers sizes up to 16 in. (406 mm) OD and wall thicknesses of 0.020 in. (0.51 mm) and over.]*

ASTM A276 Standard Specification for Stainless Steel Bars and Shapes

*Chemical composition and mechanical properties for bars including rounds, squares, and hot-rolled or extruded shapes such as angles, tees and channels.*

ASTM A479/479M Standard Specification for Stainless Steel Bars and Shapes for Use in Boilers and Other Pressure Vessels

*Chemical composition and mechanical properties for hot- and cold-finished bars of stainless steel, including rounds, squares, and hexagons, and hot-rolled and extruded shapes such as angles, tees, and channels for use in boiler and pressure vessel construction.*

ASTM A484/A484M Standard Specification for General Requirements for Stainless Steel Bars, Billets, and Forgings

*Dimensional tolerance, straightness, and finish descriptions for hot- or cold-finished bar, squares, angles, channels, tees and other shapes. The finish descriptions are very general.*

ASTM A1069/A1069M Standard Specification for Laser-Fused Stainless Steel Bars, Plates and Shapes.

*Ordering information, manufacture, materials etc. relating to laser-fused stainless steel bars, plates, and shapes of structural quality for use in bolted or welded structural applications. (Note: Laser fusion is a laser welding process without the use of filler material.)*

The relevant standard for welding stainless steel is AWS D1.6/D1.6M, *Structural Welding Code: Stainless steel*. All sections should be welded in line with a general welding procedure specification in accordance with AWS D1.6/D1.6M.

Note that the design wall thickness is equal to the nominal wall thickness for stainless steel square and rectangular HSS. (This differs from the requirement for electric-resistance-welded HSS made from carbon steel where the design wall thickness is equal to 0.93 times the nominal wall thickness.)

## 1.4 Designation system

The tables cover welded W- and S-shapes and hot rolled S-shapes. Hot rolled S-shapes have a nominal slope of 16.67% on the inner flange surface. W- and S-shapes are designated by the mark W or S, followed by the nominal depth (in.) and nominal weight (lb/ft).

The tables cover welded and hot rolled C-shapes and welded MC-shapes. Hot rolled C-shapes have a nominal slope of 16.67% on the inner flange surface. C- and MC-shapes are designated by the mark C or MC, followed by the nominal depth (in.) and nominal weight (lb/ft).

The tables cover welded and hot rolled Angles (also known as L-shapes). They are designated by the mark L, followed by the leg sizes (in.) and thickness (in.).

The tables cover roll formed and brake pressed square and rectangular hollow structural sections (HSS). Rectangular HSS are designated by the mark HSS, overall outside dimensions (in.), and wall thickness (in.).

The round HSS are designated by the term HSS, nominal outside diameter (in.), and wall thickness (in.) with both dimensions expressed to three decimal places.

The pipe are designated by the term Pipe, nominal diameter (in.) and weight class (Std).

## 1.5 Dimensional, property, mass and force units

The dimensions of sections and section properties are given in inches. The nominal weight is given in lb/foot. The strengths are given in kip (kilopound) per square inch (ksi) where a kip is 1000 lb-force.

Tabulated decimal values are appropriate for use in design calculations, whereas fractional values are appropriate for use in detailing.

## 1.6 Axis convention

The convention adopted throughout this publication is:

x-x axis	major principal (i.e. strong) axis for W-, S-, C-, MC-shapes and rectangular HSS
y-y axis	minor principal (i.e. weak) axis for W-, S-, C-, MC-shapes and rectangular HSS
x-x axis	rectangular axis for single equal angles
z-z axis	minor principal axis for single angles

# SECTION PROPERTIES

## 2.1 Open sections

The properties for the hot rolled sections were taken from the AISC Shapes Database v14.1 and take into account all tapers, radii and fillets of the sections. Some smaller angle sections were not included in the database and their properties were calculated from first principles, with the assumptions regarding internal and external radii taken from Reference 4.

The following sections give the expressions used for calculating the properties for the welded sections, with negligible radii and fillets assumed.

### 2.1.1 Area

For W-shapes and S-shapes:

$$A = (d \times b_f) - (d - 2t_f)(b_f - t_w)$$

For C-shapes and MC-shapes:

$$A = (2t_f b_f) + (d - 2t_f)t_w$$

For angles:

$$A = bt + (b - t)t$$

### 2.1.2 Detailing dimensions $k$ , $k_1$ , $T$ and workable gage

The following assumptions were made:

$$k = t_f$$

$$k_1 = \frac{t_w}{2}$$

$$T = d - 2k$$

The values for workable gages for hot rolled sections were assumed to apply to the welded sections of equivalent size. Where no values were available for hot rolled sections, engineering judgement was used to determine values.

### 2.1.3 Moment of inertia ( $I$ ), $\bar{x}$ and $\bar{y}$

For W- and S-shapes:

$$I_x = \frac{b_f d^3}{12} - \frac{(b_f - t_w)(d - 2t_f)^3}{12}$$

$$I_y = \frac{t_f b_f^3}{6} + \frac{(d - 2t_f)t_w^3}{12}$$

For M- and MC-shapes:

$$I_x = \frac{b_f d^3}{12} - \frac{(b_f - t_w)(d - 2t_f)^3}{12}$$

$$I_y = \frac{t_f b_f^3}{6} + (2b_f t_f) \left( \frac{b_f}{2} - \bar{x} \right)^2 + \frac{(d - 2t_f)t_w^3}{12} + (d - 2t_f)t_w \left( \frac{t_w}{2} - \bar{x} \right)^2$$

Where  $\bar{x}$  is the horizontal distance from the outer edge of the channel web to the centre of gravity and is given by:

$$\bar{x} = \frac{t_f b_f^2 + \left( \frac{(d - 2t_f)t_w^2}{2} \right)}{A}$$

For equal angles:

$$I_x = \frac{tb^3}{12} + \left( tb \left( \frac{b}{2} - \bar{y} \right)^2 \right) + \frac{(b-t)t^3}{12} + t(b-t) \left( \frac{t}{2} - \bar{y} \right)^2$$

Where  $\bar{y}$  is the vertical distance from the designated edge of member to the center of gravity and is given by:

$$\bar{y} = \frac{t^2(b-t) + (b^2t)}{2A}$$

(The properties around the y-y axis are identical for equal angles.)

#### 2.1.4 Radius of gyration ( $r$ )

The radius of gyration is derived as follows:

$$r = \sqrt{\frac{I}{A}}$$

#### 2.1.5 Elastic section modulus ( $S$ )

The elastic section modulus is used to calculate the elastic design resistance for bending or to calculate the stress at the extreme fibre of the section due to a moment. It is derived as follows:

For W- and S-shapes:

$$S_x = \frac{I_x}{\left( \frac{d}{2} \right)}$$

$$S_y = \frac{I_y}{\left( \frac{b_f}{2} \right)}$$

For M- and MC-shapes

$$S_x = \frac{I_x}{\left( \frac{d}{2} \right)}$$

$$S_y = \frac{I_y}{\left(\frac{b_f}{2}\right)}$$

For equal angles:

$$S_x = \frac{I_x}{b - \bar{y}}$$

For channels and angles, the elastic section modulus about the minor (y-y) axis is given for the extreme fibre at the toe(s) of the section only.

### 2.1.6 Plastic section modulus (Z)

The plastic section modulus,  $Z$ , is the sum of the first moments of area of all the elements in the cross-section about the equal area axis of the cross-section.

For W- and S-shapes:

$$Z_x = b_f t_f (d - t_f) + \frac{t_w (d - 2t_f)^2}{4}$$

$$Z_y = \frac{t_f b_f^2}{2} + \frac{(d - 2t_f) t_w^2}{4}$$

For C- and MC-shapes:

$$Z_x = b_f t_f (d - t_f) + \frac{t_w (d - 2t_f)^2}{4}$$

$$x_p > t_w \quad Z_y = t_f x_p^2 + t_f (b_f - x_p)^2 + t_w (d - 2t_f) \left(x_p - \frac{t_w}{2}\right)$$

$$x_p \leq t_w: \quad Z_y = t_f x_p^2 + t_f (b_f - x_p)^2 + (d - 2t_f) \frac{x_p^2}{2} + (d - 2t_f) \frac{(t_w - x_p)^2}{2}$$

$x_p$  is the horizontal distance from the designated edge of member to its plastic neutral axis (for y-y bending) and depends on whether the plastic neutral axis lies within or outside the web:

$$t_w > \frac{b_f}{1 - \frac{d}{2t_f}} \quad x_p = b_f - \left(\frac{A}{4t_f}\right)$$

$$t_w \leq \frac{b_f}{1 - \frac{d}{2t_f}} \quad x_p = \frac{A}{2d}$$

For equal angles:

$$Z_x = \frac{b(t - y_p)^2 + 2t(b - t) \left(t - y_p + \frac{b - t}{2}\right) + y_p^2 b}{2}$$

$y_p$  is the vertical distance from the designated edge of the member to its plastic neutral axis and is given by:



$$y_p = \frac{A}{2b}$$

### 2.1.7 Effective radius of gyration $r_{ts}$

For W-, S-, M- and MC-shapes, the parameter  $r_{ts}$  is used in the calculation of the limiting length  $L_r$  for doubly symmetric I-shaped members and channels bent about their major axis.  $r_{ts}$  is given by:

$$r_{ts} = \sqrt{\frac{\sqrt{I_y C_w}}{S_x}} \quad (\text{Spec. Eq. F2-7})$$

### 2.1.8 Distance between flange centroids ( $h_0$ )

For W-, S-, M- and MC-shapes:

$$h_0 = d - t_f$$

### 2.1.9 Shear Centre ( $e_0$ )

For M- and MC-shapes, the shear centre was calculated from Equation 3.19 of the AISC Design Guide 9, *Torsional Analysis of Structural Steel Members* (DG9)<sup>[5]</sup>:

$$e_0 = \frac{t_f \left( b_f - \left( \frac{t_w}{2} \right) \right)^2}{2t_f \left( b_f - \left( \frac{t_w}{2} \right) \right) + \frac{t_w(d - t_f)}{3}} - \frac{t_w}{2}$$

### 2.1.10 Torsional properties ( $J$ and $C_w$ )

For W- and S-shapes:

$J$  was determined using the more accurate expressions in DG9<sup>[5]</sup> (Equation C.19) with both internal and external radius set to zero.  $C_w$  was determined from Equation 3.5 of AISC DG9.

$$J = \frac{2b_f t_f^3}{3} + \frac{(d - 2t_f)t_w^3}{3} + \left[ 2 \left( -0.042 + \left( 0.22 \frac{t_w}{t_f} \right) - \left( 0.0725 \left( \frac{t_w}{t_f} \right)^2 \right) \right) \left( t_f + \frac{t_w^2}{4t_f} \right)^4 - (0.42t_f^4) \right]$$

$$C_w = \frac{I_y(d - t_f)^2}{4}$$

For M- and MC-shapes

$J$  was determined using the more accurate expressions in DG9<sup>[5]</sup> (Equation C.28) with both internal and external radius set to zero.  $C_w$  was determined from Equation 3.18 of DG9.

$$J = \frac{2b_f t_f^3}{3} + \frac{(d - 2t_f)t_w^3}{3} + \left[ 2 \left( -0.0908 + \left( 0.2621 \frac{t_w}{t_f} \right) - \left( 0.0945 \left( \frac{t_w}{t_f} \right)^2 \right) \right) \left( 2 \left( t_f + t_w - \sqrt{2t_f t_w} \right) \right)^4 - (0.42t_f^4) \right]$$

$$C_w = \frac{(d - t_f)^2 \left( b_f - \left( \frac{t_w}{2} \right) \right)^2 t_f (b_f - 2t_w - 3e_0)}{6} + \left[ \left( e_0 - \left( \frac{t_w}{2} \right) \right)^2 I_x \right]$$

$\bar{r}_0$ , the polar radius of gyration about the shear centre and  $H$ , a flexural constant, were calculated as:

$$\bar{r}_0 = \sqrt{(\bar{x} + e_0)^2 + \frac{I_x + I_y}{A}} \quad (\text{Spec. Eq. E4-11})$$

$$H = 1 - \frac{(\bar{x} + e_0)^2}{\bar{r}_0^2} \quad (\text{Spec. Eq. E4-10})$$

For equal angles:

$J$  was determined from equation 3.4 and  $C_w$  was determined from Equation 3.34 of DG9<sup>[5]</sup> however since pure torsional shear stresses will generally dominate over warping stresses, it should be noted that stresses due to warping are usually neglected in single angles. The expression for  $\bar{r}_0$  assumes the shear centre lies at the intersection of the centrelines of the legs.

$$J = \frac{At^2}{3}$$

$$C_w = \frac{t^3 b^3}{18}$$

$$\bar{r}_0 = \sqrt{\frac{I_x + I_y}{A} + 2 \left( \bar{x} - \frac{t}{2} \right)^2} \quad (\text{Spec. Eq. E4-11})$$

### 2.1.11 Compact Section Criteria, Section classification and $Q_s$

For W-shapes:

In the expression  $h/t_w$ ,  $h = d - 2t_f$

The tables for W-shapes indicate if a section is slender when subject to compression or if a section exceeds the compact limit for flexure for the two strength classes (determined in accordance with Table 3-1 and 3-2 of DG27).

Under major axis bending, for 30 ksi, all the webs are compact and all the flanges are compact except W14x90 and W6x15 which have non-compact flanges. For 65 ksi all the webs are compact except for W24x68, W24x55, W21x44, W18x35, W16x31, W16x26, W14x22, W12x14 which are all non-compact. For 65 ksi, all the flanges are compact or non-compact except W14x90 and W6x15 which are slender.

Under compression, about half of the shapes have slender webs at 30 ksi and most of the shapes have slender webs at 65 ksi. All the flanges are non-slender at both strength levels except for W14x90 and W6x15 in 65 ksi stainless steel.

The tables also indicate when the web shear coefficient  $C_p$  is less than 1.0 for webs without transverse stiffeners, i.e. when:

$$\frac{h}{t_w} \leq 1.1 \sqrt{k_v E / F_y} \quad (\text{Spec. Eq. G2-3})$$

With  $k_v = 5$  for webs without transverse stiffeners and with  $h/t_w < 260$ .

For S-shapes:

In the expression  $h/t_w$ ,  $h = d - 2t_f$

All the sections are compact under major axis bending and non-slender under compression.

For C-shapes:

In the expression  $h/t_w$ ,  $h = d - 2t_f$

All the shapes are compact under major axis bending at 30 ksi and 65 ksi.

All the flanges are non-slender under compression. All the 30 ksi webs are non-slender except for C12x21.7 and C10x15.3. About two thirds of the 65 ksi webs are non-slender.

For MC-shapes:

Under major axis bending, the webs are compact at 30 ksi and 65 ksi. The flanges at 30 ksi are compact except for MC8x19.8 and MC6x10 (non-compact) and MC8x13.5 (slender). The flanges at 65 ksi are slender for MC8x19.8, MC8x13.5 and MC6x10. The flanges at 65 ksi are non-compact for MC6x14.6, MC4x6.5, MC4x6.1, MC3x3.5 and MC2x1.6.

Under compression, the flanges are non-slender except for MC8x13.5 at 30 ksi and MC8x19.8, MC8x13.5 and MC6x10. The webs are all non-slender except for MC8x13.5 at 65ksi.

For Angles:

The table for angles indicates if a section is slender when subject to compression and gives values for the net reduction factor  $Q_s$ . As the scope of DG27 does not cover slender angles, it does not give an expression for calculating  $Q_s$  for angles. However, the tables give a conservative estimate for  $Q_s$ , modifying Spec. equations (E7-10), (E7-11) and (E7-12):

$$\frac{b}{t} \leq 0.38 \sqrt{\frac{E}{F_y}} \quad Q_s = 1.0 \quad (\text{modified Spec. Eq. E7-10})$$

$$0.38 \sqrt{\frac{E}{F_y}} < \frac{b}{t} \leq 0.69 \sqrt{\frac{E}{F_y}} \quad Q_s = 1.415 - 1.10 \left(\frac{b}{t}\right) \sqrt{\frac{F_y}{E}} \quad (\text{modified Spec. Eq. E7-11})$$

$$\frac{b}{t} > 0.69 \sqrt{\frac{E}{F_y}} \quad Q_s = \frac{0.32E}{F_y \left(\frac{b}{t}\right)^2} \quad (\text{modified Spec. Eq. E7-12})$$

## 2.2 Hollow sections

Section properties are given for both cold roll formed and brake pressed square and rectangular hollow sections. For the same overall dimensions and wall thickness, the section properties of roll formed and brake pressed sections are different because the corner radii are different.

### 2.2.1 Internal corner radius

For the roll formed square and rectangular HSS, the external radius was assumed to be the maximum values given in Table 5 of ASTM A554 (see Table 2.1 of these Explanatory Notes).

For 0.375 to 0.5 in. wall thickness, the maximum external corner radius was taken as 1.2 in. (as given in Stalatable technical brochure) because no value was given in ASTM A554 for sections thicker than 0.375 in.

Table 2.1  
External radii of  
square and  
rectangular  
hollow sections  
(ASTM A554)

Wall thickness (in.)	Radii of corners, max (in.)	Wall thickness (mm)	Radii of corners, max (mm)
0.049 < t ≤ 0.065	0.125	1.24 < t ≤ 1.65	3.2
0.065 < t ≤ 0.083	0.141	1.65 < t ≤ 2.11	3.6
0.083 < t ≤ 0.095	0.188	2.11 < t ≤ 2.42	4.8
0.095 < t ≤ 0.109	0.203	2.42 < t ≤ 2.77	5.2
0.109 < t ≤ 0.134	0.219	2.77 < t ≤ 3.40	5.6
0.134 < t ≤ 0.156	0.250	3.40 < t ≤ 3.96	6.4
0.156 < t ≤ 0.200	0.375	3.96 < t ≤ 5.08	9.5
0.200 < t ≤ 0.250	0.500	5.08 < t ≤ 6.35	12.7
0.250 < t ≤ 0.375	0.750	6.35 < t ≤ 9.53	19.1
0.375 < t ≤ 0.500 <sup>1)</sup>	1.200	9.53 < t ≤ 12.7	30.5

<sup>1)</sup> Not included in ASTM A554

For the brake pressed sections, the external radius was assumed to be 2.5t for all thicknesses.

### 2.2.2 Area

For square and rectangular HSS

$$A = 2t(B + H - 2t) - (4 - \pi)(r_o^2 - r_i^2)$$

The surface area in ft<sup>2</sup>/ft is given by:

$$SA = \frac{H + B + (\pi - 4)r_o}{6}$$

For round HSS:

$$A = \frac{\pi(D^2 - d^2)}{4}$$

Where the inside diameter,  $d = D - 2t$

### 2.2.3 Moment of inertia

For square and rectangular HSS

$$I_x = \left[ \frac{BH^3}{12} - \frac{(B-2t)(H-2t)^3}{12} - 4(I_g + A_g h_g^2) + 4(I_\xi + A_\xi h_\xi^2) \right]$$

$$I_y = \left[ \frac{HB^3}{12} - \frac{(H-2t)(B-2t)^3}{12} - 4(I_g + A_g h_g^2) + 4(I_\xi + A_\xi h_\xi^2) \right]$$

Where:

$$A_g = \left(1 - \frac{\pi}{4}\right) r_o^2 \quad \text{and} \quad A_\xi = \left(1 - \frac{\pi}{4}\right) r_i^2$$

For the major axis:

$$h_g = \frac{H}{2} - \left(\frac{10-3\pi}{12-3\pi}\right) r_o \quad \text{and} \quad h_\xi = \frac{H-2t}{2} - \left(\frac{10-3\pi}{12-3\pi}\right) r_i$$

For the minor axis, substitute  $B$  for  $H$  in the expressions for  $h_g$  and  $h_\xi$

$$I_g = \left(\frac{1}{3} - \frac{\pi}{16} - \frac{1}{3(12-3\pi)}\right) r_o^4$$

$$I_\xi = \left(\frac{1}{3} - \frac{\pi}{16} - \frac{1}{3(12-3\pi)}\right) r_i^4$$

For round HSS:

$$I = \frac{\pi}{64} (D^4 - d^4)$$

### 2.2.4 Elastic section modulus (S)

For square and rectangular HSS

$$S_x = \frac{2I_x}{H}$$

$$S_y = \frac{2I_y}{B}$$

For round HSS:

$$S = \frac{2I}{D}$$

### 2.2.5 Plastic section modulus (Z)

For square and rectangular HSS

$$Z_x = \left[ \frac{BH^2}{4} - \frac{(B-2t)(H-2t)^2}{4} - 4(A_g h_g) + 4(A_\xi h_\xi) \right]$$

$$Z_y = \left[ \frac{HB^2}{4} - \frac{(H-2t)(B-2t)^2}{4} - 4(A_g h_g) + 4(A_\xi h_\xi) \right]$$

For round HSS:

$$S = 0.167(D^3 - d^3)$$

### 2.2.6 Torsional properties (J and C)

For square and rectangular HSS

$$J = \left[ t^3 \frac{h}{3} + 2KA_h \right]$$

$$C = \left[ \frac{J}{t + K/t} \right]$$

where:

$$h = 2[(B-t) + (H-t)] - 2R_c(4-\pi)$$

$$A_h = [(B-t)(H-t)] - R_c^2(4-\pi)$$

$$K = \frac{2A_h t}{h}$$

$$R_c = \frac{r_o + r_i}{2}$$

For round HSS:

$$J = 2I$$

$$C = 2S$$

### 2.2.7 Compact section criteria

For square and rectangular HSS, in the expressions  $b/t$  and  $h/t$ ,  $b = B - 2r_o$  and  $h = H - 2r_o$  where  $r_o$  is the maximum value for the external radius given in ASTM A554 for roll formed sections or  $2.5t$  for brake pressed sections.

# DESIGN OF FLEXURAL MEMBERS

The tables apply to members subject to bending about one principal axis. The members are classified in accordance with Section 4 of DG27. The tables do not include strengths for angles in flexure or sections in flexure where the web is classified as slender because they are outside the scope of DG27. An entry of 'S' in the tables denotes a section which has a slender web under flexure.

The design flexural strength,  $\phi_b M_n$ , and the allowable flexural strength,  $M_n/\Omega_b$ , were determined using the following resistance and safety factors:

$$\phi_b = 0.90 \text{ (LRFD)} \quad \Omega_b = 1.67 \text{ (ASD)}$$

The design shear strength,  $\phi_v V_n$ , and the allowable shear strength,  $V_n/\Omega_v$ , were determined using the following resistance and safety factors:

$$\phi_v = 0.90 \text{ (LRFD)} \quad \Omega_v = 1.67 \text{ (ASD)}$$

In Tables 2-1 and 3-1, W-shapes are sorted in descending order by strong-axis flexural strength and then grouped in ascending order by weight with the lightest W-shape in each range in bold. Strong-axis available strengths in flexure and shear are given for W-shapes.  $C_b$  is taken as unity.

For compact W-shapes, when  $L_b \leq L_p$ , the strong-axis available flexural strength,  $\phi_b M_{px}$  or  $M_{px}/\Omega_b$ , can be determined using the tabulated strength values. When  $L_p < L_b \leq L_r$ , it is necessary to linearly interpolate between the available strength at  $L_p$  and the available strength at  $L_r$  as follows:

$$\phi_b M_n = C_b [\phi_b M_{px} - \phi_b BF(L_b - L_p)] \leq \phi_b M_{px} \quad \text{ASD}$$

$$\frac{M_n}{\Omega_b} = C_b \left[ \frac{M_{px}}{\Omega_b} - \frac{BF}{\Omega_b} (L_b - L_p) \right] \leq \frac{M_{px}}{\Omega_b} \quad \text{LRFD}$$

(Note that these values are not tabulated.)

Where:

$$BF = \frac{(M_{px} - M_{rx})}{(L_r - L_p)}$$

$L_p$  is given by modified Spec. Eq. F2-5 for compact I-shaped members/channels, and also for I-shaped members/channels with compact webs and non-compact or slender flanges. It is given by modified Spec. Eq. F4-7 for I shaped members with non-compact webs from DG27

$L_r$  is given by Spec. Eq. F2-6 for compact I-shaped members and channels or Spec. F4-8 for other I shaped members with compact or non-compact webs

$$M_{px} = F_y Z_x$$

$$M_{rx} = 0.45 F_y S_x$$

The following modified *Spec. Eq. F3-2* was used for W- and MC-shapes with compact webs and slender flanges. The modification was needed in order to avoid a discontinuity with *Spec. Eq. F3-1* because of the different  $\lambda_{pf}$  and  $\lambda_{rf}$  limits for stainless steel.

$$M_n = \frac{0.155ES_x}{\lambda^2} \quad \text{modified Spec. Eq. F3-2}$$

For the same reason, the following modified *Spec. Eq. F4-14* is applicable for W- and S-shapes with non-compact webs and slender flanges, although in practice this expression was not used because the sections with slender flanges had compact webs, so were designed using modified *Spec. Eq. F3-2*.

$$M_n = \frac{0.155ES_{xc}}{\lambda^2} \quad \text{modified Spec. Eq. F4-14}$$

The following modified *Spec. Eq. F6-4* was used for W-, S-, C- and MC-shapes bent about their minor axis with slender flanges. The modification was needed in order to avoid a discontinuity with *Spec. Eq. F6-2* because of the different  $\lambda_{pf}$  and  $\lambda_{rf}$  limits for stainless steel.

$$F_{cr} = \frac{0.155E}{\left(\frac{b}{t_f}\right)^2} \quad \text{modified Spec. Eq. F6-4}$$

Table 3.1 of these explanatory notes summarises the equations used to calculate the nominal flexural strength  $M_n$ .

In Tables 2-2 and 3-2, W-shapes are sorted in descending order by weak-axis flexural strength and then grouped in ascending order by weight with the lightest W-shape in each range in bold. Weak axis available strengths in flexure are given for W-shapes.  $C_b$  is taken as unity. For non-compact W shapes, the tabulated values have been adjusted to account for the non-compactness. The weak axis available shear strength must be checked independently.

In Tables 2-3 and 3-3, maximum total uniform loads on braced ( $L_b \leq L_p$ ) simple-span beams bent about the strong axis are given for W-shapes. The uniform load constant,  $\phi_b M_c$  or  $M_c/\Omega_b$ , (kip-ft), divided by the span length,  $L$  (ft), provides the maximum total uniform load (kips) for a braced simple-span beam bent about the strong axis. This is based on the available flexural strength as calculated in accordance with Table 3.1 of these explanatory notes.

The strong-axis available shear strength,  $\phi_v V_n$  or  $V_n/\Omega_v$ , can be determined using the tabulated value. Above the heavy horizontal line in the tables, the maximum total uniform load is limited by the strong-axis available shear strength. The tabulated values can also be used for braced simple-span beams with equal concentrated loads spaced as shown in Table 3-22a of the *AISC Steel Construction Manual* if the concentrated loads are first converted to an equivalent uniform load.

The subsequent tables for S-, C- and MC-shapes give equivalent maximum total uniform loads to Tables 2-3 and 3-3.



Table 3.1  
Calculation of  
 $M_n$ ,  $M_r$ ,  $L_p$  and  $L_r$

Web	Flange	$M_n$	$M_r$	$L_p$	$L_r$
<b>Open sections – Strong axis bending</b>					
Compact	Compact	Spec. Eq. F2-1	$0.45F_y S_x$	Modified Spec. Eq. F2-5	Spec. Eq. F2-6
Compact	Non-compact	Spec. Eq. F3-1	$0.45F_y S_x$	$L_p'$ is tabulated, using AISC Steel Construction Manual Eq. 3-2, with $L_p$ from modified Spec. Eq. F2-5	Spec. Eq. F2-6
Compact	Slender	Modified Spec. Eq. F3-2	$0.45F_y S_x$	Not tabulated	
Non-compact	Compact or non-compact	Smallest of Spec. Eq. 4-1 or Spec. Eq. 4-13	$0.45F_y S_x$	Modified Spec. Eq. 4-7	Spec. Eq. F4-8
<b>Open sections - Weak axis bending</b>					
N/A	Compact	Spec. Eq. F6-1	N/A	N/A	N/A
N/A	Non-compact	Smallest of Spec. Eq. F6-2 and Spec. Eq. F6-1	N/A	N/A	N/A
N/A	Slender	Smallest of Spec. Eq. F6-3 (based on modified Spec. Eq. F6-4) and Spec. Eq. F6-1	N/A	N/A	N/A
<b>Hollow sections</b>					
Compact	Compact	Spec. Eq. F7-1	N/A	N/A	N/A
Compact	Non-compact	Modified Spec. Eq. F7-2	N/A	N/A	N/A
Compact	Slender	Spec. Eq. F7-3	N/A	N/A	N/A
Non-compact	Compact	Modified Spec. Eq. F7-5	N/A	N/A	N/A
Non-compact	Non-compact	Smallest of modified Spec. Eq. F7-2 or modified Spec. Eq. F7-5	N/A	N/A	N/A
Non-compact	Slender	Smallest of Spec. Eq. F7-3 or modified Spec. Eq. F7-5	N/A	N/A	N/A

The calculation procedure for channels is the same as for I-shaped sections apart from for the calculation of the coefficient  $c$  in the calculation of  $L_r$  (Spec. Eq. F2-8b). For carbon steel, the C-shapes and MC-shapes are all compact, hence no rules are given for determining the flexural strength for channels with non-compact or slender flanges. However, in stainless steel, some of the MC-shapes have non-compact or slender flanges. For these sections, it was assumed that the rules for carbon steel I-shaped members with non-compact or slender flanges applied, with the coefficient  $c$  calculated for channels.

For hollow sections, the tables give the available flexural strength. For non-compact and slender cross-sections, the tabulated values have been adjusted to account for non-compactness and slenderness.

Very long rectangular HSS bent about the major axis will be susceptible to lateral torsional buckling. However, the tables do not determine strengths for this limit state for rectangular HSS since beam deflection will control for all reasonable cases.

# DESIGN OF COMPRESSION MEMBERS

The tables give the available strength in axial compression for W-shapes, angles and hollow sections. The compression members are classified in accordance with Section 4 of DG27. They do not include values for the strength of slender leg angles or slender round HSS because they are outside the scope of DG27.

The available strength of compression members,  $\phi_c P_n$  or  $P_n/\Omega_c$  is determined according to Section 5 of DG27, using modified Spec. Eq E3-2 and modified Spec. E3-3 as appropriate.

The nominal compressive strength,  $P_n$ , was determined using the following resistance and safety factors:

$$\phi_c = 0.85 \text{ (LRFD)} \quad \Omega_c = 1.76 \text{ (ASD)} \text{ for round HSS}$$

$$\phi_c = 0.90 \text{ (LRFD)} \quad \Omega_c = 1.67 \text{ (ASD)} \text{ for all other structural sections}$$

Reference should be made to Part 4 of the AISC *Steel Construction Manual* for information on the effective length and column slenderness.

The available strengths in axial compression tabulated for W-shapes and rectangular HSS are given for the effective length with respect to the y-axis  $(KL)_y$ . However, the effective length with respect to the x-axis  $(KL)_x$  must also be investigated. To determine the available strength in axial compression, the table should be entered at the larger of  $(KL)_y$  and  $(KL)_{y \text{ eq}}$ , where:

$$(KL)_{y \text{ eq}} = \frac{(KL)_x}{\frac{r_x}{r_y}} \quad \text{AISC Steel Construction Manual Eq. (4-1)}$$

Values of the ratio  $r_x/r_y$  and other properties useful in design of compression members are listed at the bottom of each table.

For W-shapes, variables  $P_{wo}$ ,  $P_{wi}$ ,  $P_{wb}$  and  $P_{fb}$  shown in Table 4-1 of the AISC *Steel Construction Manual* can be used to determine the strength of W-shapes without stiffeners to resist concentrated forces applied normal to the face(s) of the flange(s), based on the AISC *Specification* Section J.10 and Part 4 of the AISC *Steel Construction Manual*.

The following resistance and safety factors were used:

$$\phi_c = 1.00 \text{ (LRFD)} \quad \Omega_c = 1.50 \text{ (ASD)} \text{ for } P_{wo} \text{ and } P_{wi}$$

$$\phi_c = 0.90 \text{ (LRFD)} \quad \Omega_c = 1.67 \text{ (ASD)} \text{ for } P_{wb} \text{ and } P_{fb}$$

Available strengths in axial compression are given for single angles, loaded through the centroid of the cross section, based upon the effective length with respect to the z-axis,  $(KL)_z$ . Single angles may be assumed to be loaded through the centroid when the requirements of the AISC *Specification* Section E5 are met, as in these cases the eccentricity is accounted for and the slenderness is reduced by the restraining effects of the support at both ends of the member.

# REFERENCES

- 1 AISC Design Guide 27, Structural Stainless Steel, Baddoo, 2013
- 2 Specification for Structural Steel Buildings, ANSI/AISC 360-10, AISC 2010
- 3 Steel Construction Manual, Fourteenth Edition, AISC, 2010
- 4 [www.roymech.co.uk/Useful\\_Tables/Sections/Angle\\_dim.htm](http://www.roymech.co.uk/Useful_Tables/Sections/Angle_dim.htm)
- 5 AISC Design Guide 9, Torsional Analysis of Structural Steel Members, Seaburg and Carter, 1997

## **STRUCTURAL STAINLESS STEEL DESIGN TABLES** **IN ACCORDANCE WITH AISC DG27: STRUCTURAL STAINLESS STEEL**

This publication presents design data derived in accordance with the American Institute of Steel Construction's Design Guide 27 *Structural Stainless Steel*. The data is presented in an equivalent set of tables to those in the AISC *Steel Construction Manual* for carbon steel sections. Tables cover dimensions and properties, design data for flexural members and design data for compression members. Two strength levels are covered – 30 ksi which corresponds to austenitic stainless steels and 65 ksi which corresponds to duplex stainless steels.

The following structural sections are included in this publication:

- W- and S-shapes
- C- and MC-shapes
- Equal angles
- Rectangular hollow structural sections (HSS)
- Square HSS
- Circular HSS.

Section ranges listed cover sections that are readily available at the time of printing.

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