# Table A.4.3
# NOMINAL STRENGTHS OF WROUGHT ALUMINUM PRODUCTS

| ALLOY | TEMPER | ASTM SPECIFICATION, PRODUCT | THICKNESS in | | $F_{tu}$ | $F_{ty}$ | $F_{tuw}$ | $F_{tyw}$ | $k_t$ |
|---|---|---|---|---|---|---|---|---|---|
| | | | from | to | ksi | ksi | ksi | ksi | |
| 1060 | H12[1] | B209, sheet & plate | 0.017 | 2.000 | 11 | 9 | 8 | 2.5 | 1 |
| 1060 | H12 | B210, drawn tube | 0.010 | 0.500 | 10 | 4 | 8.5 | 2.5 | 1 |
| 1060 | H14[1] | B209, sheet & plate | 0.009 | 1.000 | 12 | 10 | 8 | 2.5 | 1 |
| 1060 | H14 | B210, drawn tube | 0.010 | 0.500 | 12 | 10 | 8.5 | 2.5 | 1 |
| 1100 | H12[1] | B209, sheet & plate | 0.017 | 2.000 | 14 | 11 | 11 | 3.5 | 1 |
| 1100 | H12 | B210, drawn tube | 0.014 | 0.500 | 14 | 11 | 11 | 3.5 | 1 |
| 1100 | H14[1] | B209, sheet & plate | 0.009 | 1.000 | 16 | 14 | 11 | 3.5 | 1 |
| 1100 | H14 | B210, drawn tube | 0.014 | 0.500 | 16 | 14 | 11 | 3.5 | 1 |
| 2014 | T6 | B209, sheet & plate | 0.040 | 0.249 | 66 | 58 | – | – | 1.25 |
| 2014 | T651 | B209, sheet & plate | 0.250 | 2.000 | 67 | 59 | – | – | 1.25 |
| 2014 | T6, T6510, T6511 | B221, extrusion | – | 0.499 | 60 | 53 | – | – | 1.25 |
| 2014 | T6, T651 | B211, bar, rod, & wire | 0.125 | 8.000 | 65 | 55 | – | – | 1.25 |
| 2014 | T6 | B210, drawn tube | 0.018 | 0.500 | 65 | 55 | – | – | 1.25 |
| Alclad 2014 | T6 | B209, sheet & plate | 0.025 | 0.039 | 63 | 55 | – | – | 1.25 |
| Alclad 2014 | T6 | B209, sheet & plate | 0.040 | 0.249 | 64 | 57 | – | – | 1.25 |
| Alclad 2014 | T651 | B209, sheet & plate | 0.250 | 0.499 | 64 | 57 | – | – | 1.25 |
| 2219 | T87 | B209, sheet & plate | 0.250 | 3.000 | 64 | 51 | 35 | 26 | 1.25 |
| 3003 | H12[1] | B209, sheet & plate | 0.017 | 2.000 | 17 | 12 | 14 | 5 | 1 |
| 3003 | H12 | B210, drawn tube | 0.010 | 0.500 | 17 | 12 | 14 | 5 | 1 |
| 3003 | H14[1] | B209, sheet & plate | 0.009 | 1.000 | 20 | 17 | 14 | 5 | 1 |
| 3003 | H14 | B210, drawn tube | 0.010 | 0.500 | 20 | 17 | 14 | 5 | 1 |
| 3003 | H16[1] | B209, sheet & plate | 0.006 | 0.162 | 24 | 21 | 14 | 5 | 1 |
| 3003 | H16 | B210, drawn tube | 0.010 | 0.500 | 24 | 21 | 14 | 5 | 1 |
| 3003 | H18[1] | B209, sheet & plate | 0.006 | 0.128 | 27 | 24 | 14 | 5 | 1 |
| 3003 | H18 | B210, drawn tube | 0.010 | 0.500 | 27 | 24 | 14 | 5 | 1 |
| Alclad 3003 | H12[1] | B209, sheet & plate | 0.017 | 2.000 | 16 | 11 | 13 | 4.5 | 1 |
| Alclad 3003 | H14[1] | B209, sheet & plate | 0.009 | 1.000 | 19 | 16 | 13 | 4.5 | 1 |
| Alclad 3003 | H16[1] | B209, sheet & plate | 0.006 | 0.162 | 23 | 20 | 13 | 4.5 | 1 |
| Alclad 3003 | H14 | B210, drawn tube | 0.010 | 0.500 | 19 | 16 | 13 | 4.5 | 1 |
| Alclad 3003 | H18 | B210, drawn tube | 0.010 | 0.500 | 26 | 23 | 13 | 4.5 | 1 |
| 3004 | H32[1] | B209, sheet & plate | 0.017 | 2.000 | 28 | 21 | 22 | 8.5 | 1 |
| 3004 | H34[1] | B209, sheet & plate | 0.009 | 1.000 | 32 | 25 | 22 | 8.5 | 1 |
| 3004 | H36[1] | B209, sheet & plate | 0.006 | 0.162 | 35 | 28 | 22 | 8.5 | 1 |
| 3004 | H38[1] | B209, sheet & plate | 0.006 | 0.128 | 38 | 31 | 22 | 8.5 | 1 |
| Alclad 3004 | H32[1] | B209, sheet & plate | 0.017 | 2.000 | 27 | 20 | 21 | 8 | 1 |
| Alclad 3004 | H34[1] | B209, sheet & plate | 0.009 | 1.000 | 31 | 24 | 21 | 8 | 1 |
| Alclad 3004 | H36[1] | B209, sheet & plate | 0.006 | 0.162 | 34 | 27 | 21 | 8 | 1 |
| 3005 | H25 | B209, sheet & plate | 0.016 | 0.080 | 26 | 22 | – | – | 1 |
| 3005 | H28 | B209, sheet & plate | 0.016 | 0.080 | 31 | 27 | – | – | 1 |
| 3105 | H25 | B209, sheet & plate | 0.013 | 0.080 | 23 | 19 | – | – | 1 |
| 5005 | H12 | B209, sheet & plate | 0.017 | 2.000 | 18 | 14 | 15 | 5 | 1 |
| 5005 | H14 | B209, sheet & plate | 0.009 | 1.000 | 21 | 17 | 15 | 5 | 1 |
| 5005 | H16 | B209, sheet & plate | 0.006 | 0.162 | 24 | 20 | 15 | 5 | 1 |
| 5005 | H32[1] | B209, sheet & plate | 0.017 | 2.000 | 17 | 12 | 15 | 5 | 1 |

$F_{ST}$ is determined using Section B.5.4.2

$\rho_{ST}$ = stiffener effectiveness ratio determined as follows:

a) $\rho_{ST} = 1.0$ for $b/t \le \lambda_e/3$ (B.5-6)

b) $\rho_{ST} = \dfrac{r_s}{9t\left(\dfrac{b/t}{\lambda_e} - \dfrac{1}{3}\right)} \le 1.0$ for $\lambda_e/3 < b/t \le \lambda_e$ (B.5-7)

c) $\rho_{ST} = \dfrac{r_s}{1.5t\left(\dfrac{b/t}{\lambda_e} + 3\right)} \le 1.0$ for $\lambda_e < b/t < 2\lambda_e$ (B.5-8)

$r_s$ = the stiffener's radius of gyration about the stiffened element's mid-thickness.

For straight stiffeners of constant thickness (see Figure B.5.3)

$r_s = (d_s \sin\theta_s)/\sqrt{3}$

where

$d_s$ = the stiffener's flat width and

$\theta_s$ = the angle between the stiffener and the stiffened element.

$$\lambda_e = 1.28\sqrt{E/F_{cy}} \qquad \text{(B.5-9)}$$

$F_c$ for the stiffened element determined using Section B.5.4.3 shall not exceed $F_c$ for the stiffener determined using Section B.5.4.1.

For flat elements

a) supported on one edge and with a stiffener on the other edge, and

b) with a stiffener of depth $D_S > 0.8b$, where $D_S$ is defined in Figure B.5.3, or with a thickness greater than the stiffener's thickness,

the stress $F_c$ corresponding to the uniform compressive strength is $F_c = F_{UT}$ .

### B.5.4.4 Flat Elements Supported on Both Edges and with an Intermediate Stiffener

The stress $F_c$ corresponding to the uniform compressive strength of flat elements supported on both edges and with an intermediate stiffener is:

| LIMIT STATE | $F_c$ | Slenderness $\lambda_s$ | Slenderness Limits |
|---|---|---|---|
| yielding | $F_{cy}$ | $\lambda_s \le \lambda_1$ | $\lambda_1 = \dfrac{B_c - F_{cy}}{D_c}$ |
| inelastic buckling | $B_c - D_c\lambda_s$ | $\lambda_1 < \lambda_s < \lambda_2$ | |
| elastic buckling | $\dfrac{\pi^2 E}{\lambda_s^2}$ | $\lambda_s \ge \lambda_2$ | $\lambda_2 = C_c$ |

where

$$\lambda_s = 4.62\frac{b}{t}\sqrt{\frac{1 + A_s/(bt)}{1 + \sqrt{1 + \dfrac{10.67 I_o}{bt^3}}}} \qquad \text{(B.5-10)}$$

$A_s$ = area of the stiffener only, not including any part of the element stiffened.

$I_o$ = moment of inertia of a section comprising the stiffener and one half of the width of the adjacent sub-elements and the transition corners between them, taken about the centroidal axis (denoted as o-o in Figure B.5.4) of the section parallel to the stiffened element.

$b$ = distance between stiffener and supporting element (see Figure B.5.4)

$t$ = thickness of the flat element supported on both edges (see Figure B.5.4)

$F_c$ shall not exceed $F_c$ determined using Section B.5.4.2 for the sub-elements of the stiffened element, and shall not exceed $F_c$ of the stiffener determined using Section B.5.4.1.

### B.5.4.5 Round Hollow Elements and Curved Elements Supported on Both Edges

The stress $F_c$ corresponding to the uniform compressive strength of round hollow elements and curved elements supported on both edges is:

| LIMIT STATE | $F_c$ | Slenderness $\lambda$ | Slenderness Limits |
|---|---|---|---|
| yielding | $F_{cy}$ | $\lambda \le \lambda_1$ | $\lambda_1 = \dfrac{B_t - F_{cy}}{D_t}$ |
| inelastic buckling | $B_t - D_t\lambda$ | $\lambda_1 < \lambda < \lambda_2$ | |
| elastic buckling | $\dfrac{\pi^2 E}{16\lambda^2\left(1 + \dfrac{\lambda}{35}\right)^2}$ | $\lambda \ge \lambda_2$ | $\lambda_2 = C_t$ |

$$\lambda = \sqrt{\frac{R_b}{t}}$$

For round hollow elements with transverse welds, use of Section B.5.4.5 is limited to elements with $R_b/t < 20$.

### B.5.4.6 Direct Strength Method

As an alternate to Sections B.5.4.1 through B.5.4.4, the stress $F_c$ corresponding to the uniform compressive strength of flat elements without welds may be determined as:

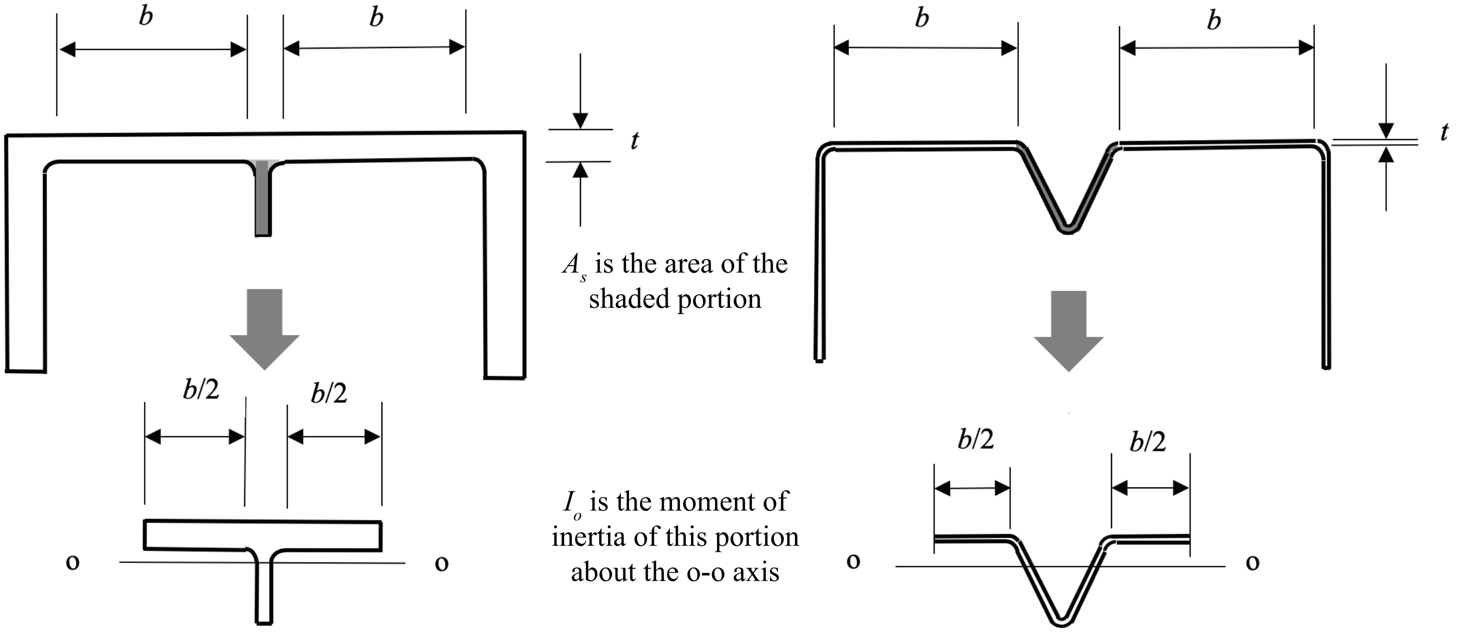


**Figure B.5.4**
**FLAT ELEMENTS WITH AN INTERMEDIATE STIFFENER**

| LIMIT STATE | $F_c$ | Slenderness $\lambda_{eq}$ | Slenderness Limits |
|---|---|---|---|
| yielding | $F_{cy}$ | $\lambda_{eq} \le \lambda_1$ | $\lambda_1 = \dfrac{B_p - F_{cy}}{D_p}$ |
| inelastic buckling | $B_p - D_p \lambda_{eq}$ | $\lambda_1 < \lambda_{eq} < \lambda_2$ | |
| post-buckling | $\dfrac{k_2\sqrt{B_p E}}{\lambda_{eq}}$ | $\lambda_{eq} \ge \lambda_2$ | $\lambda_2 = \dfrac{k_1 B_p}{D_p}$ |

$$\lambda_{eq} = \pi\sqrt{\frac{E}{F_e}} \tag{B.5-11}$$

$F_e$ = the elastic local buckling stress of the cross section determined by analysis

### B.5.5 Strength of Elements in Flexural Compression

The stress $F_b$ corresponding to the flexural compressive strength of elements is:

For unwelded elements:

$$F_b = F_{bo} \tag{B.5-12}$$

For welded elements:

$$F_b = F_{bo}(1 - A_{wzc}/A_{gc}) + F_{bw} A_{wzc}/A_{gc} \tag{B.5-13}$$

where

$F_{bo}$ = stress corresponding to the flexural compressive strength calculated using Sections B.5.5.1 through B.5.5.3 for an element if no part of the cross section were weld-affected. Use buckling constants for unwelded metal (Table B.4.1 or Table B.4.2) and $F_{cy}$.

$F_{bw}$ = stress corresponding to the flexural compressive strength calculated using Sections B.5.5.1 through B.5.5.3 for an element if the entire cross section were weld-affected. Use buckling constants for weld-affected zones (Table B.4.1) and $F_{cyw}$.

$A_{wzc}$ = cross sectional area of the weld-affected zone in compression

$A_{gc}$ = gross cross sectional area of the element in compression.

### B.5.5.1 Flat Elements Supported on Both Edges

The stress $F_b$ corresponding to the flexural compressive strength of flat elements supported on both edges and flat elements supported on the compression edge with the tension edge free is:

| LIMIT STATE | $F_b$ | Slenderness $b/t$ | Slenderness Limits |
|---|---|---|---|
| yielding | $1.5F_{cy}$ | $b/t \le \lambda_1$ | $\lambda_1 = \dfrac{B_{br} - 1.5F_{cy}}{mD_{br}}$ |
| inelastic buckling | $B_{br} - mD_{br}\, b/t$ | $\lambda_1 < b/t < \lambda_2$ | |
| post-buckling | $\dfrac{k_2\sqrt{B_{br}E}}{(mb/t)}$ | $b/t \ge \lambda_2$ | $\lambda_2 = \dfrac{k_1 B_{br}}{mD_{br}}$ |

$m = 1.15 + c_o/(2c_c)$ for $-1 < c_o/c_c < 1$
$m = 1.3/(1 - c_o/c_c)$ for $c_o/c_c \le -1$

If the leg tip is in tension, lateral-torsional buckling strength determined by Section F.5c with

$$M_e = \frac{0.73Eb^4tC_b}{L_b^2}\left[\sqrt{1+0.88(L_bt/b^2)^2}+1\right] \quad \text{(F.5-5)}$$

c) *Equal leg angles without lateral-torsional restraint*: Strengths shall be calculated with $S_c$ equal to 0.80 of the geometric section modulus.

If the leg tip is in compression, $M_n$ is the lesser of:

(1) local buckling strength determined by Section F.5a(1)

(2) lateral-torsional buckling strength determined by F.5c with

$$M_e = \frac{0.58Eb^4tC_b}{L_b^2}\left[\sqrt{1+0.88(L_bt/b^2)^2}-1\right] \quad \text{(F.5-6)}$$

If the leg tip is in tension, $M_n$ is the lesser of:

(1) yield strength determined by Section F.5b

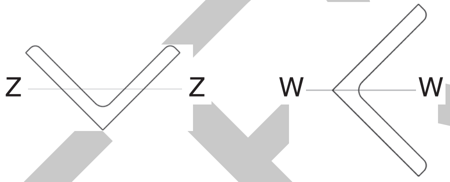
(2) lateral-torsional buckling strength determined by Section F.5c with

$$M_e = \frac{0.58Eb^4tC_b}{L_b^2}\left[\sqrt{1+0.88(L_bt/b^2)^2}+1\right] \quad \text{(F.5-7)}$$

d) *Unequal leg angles without lateral-torsional restraint*: moments about the geometric axes shall be resolved into moments about the principal axes and the angle shall be designed as an angle bent about a principal axis (Section F.5.2).

## F.5.2 Bending About Principal Axes

Bending about principal axes is shown in Figure F.5.5.



Minor Axis Bending    Major Axis Bending

Figure F.5. 5

a) *Major axis bending*: $M_n$ is the lesser of:

(1) local buckling strength determined by Section F.5a for the leg with its tip in compression

(2) lateral-torsional buckling strength determined by Section F.5c, with

$$M_e = \frac{9EAr_ztC_b}{8L_b}\left(\sqrt{1+\left(4.4\frac{\beta_wr_z}{L_bt}\right)^2}+4.4\frac{\beta_wr_z}{L_bt}\right) \quad \text{(F.5-8)}$$

$$\beta_w = \left[\frac{1}{I_w}\int z\left(w^2+z^2\right)dA\right]-2z_o \quad \text{(F.5-9)}$$

$\beta_w$ is the coefficient of monosymmetry about the major principal axis. $\beta_w$ is positive when the short leg is in compression, negative when the long leg is in compression, and zero for equal-leg angles. (See the commentary for values for common angle sizes and equations for determining $\beta_w$.) If the long leg is in compression anywhere along the unbraced length of the angle, $\beta_w$ shall be taken as negative.

$z_o$ = coordinate along the $z$-axis of the shear center with respect to the centroid

$I_w$ = moment of inertia about the major principal axis

b) *Minor axis bending*:

(1) If the leg tips are in compression, $M_n$ is the lesser of the local buckling strength determined by Section F.5a(1) and the yield strength determined by Section F.5b.

(2) If the leg tips are in tension, $M_n$ is the yield strength determined by Section F.5b.

# Chapter J Design of Connections

This chapter addresses connecting elements and connectors.

## J.1 GENERAL PROVISIONS

### J.1.1 Design Basis

The available strength of connections shall be determined in accordance with the provisions of this chapter and Chapter B.

If the longitudinal centroidal axes of connected axially loaded members do not intersect at one point, the connection and members shall be designed for the effects of eccentricity.

### J.1.2 Fasteners in Combination with Welds

Fasteners shall not be considered to share load in combination with welds.

### J.1.3 Maximum Spacing of Fasteners

The pitch and gage of fasteners joining components of tension members shall not exceed $(3 + 20t)$ in. [$(75 + 20t)$ mm] where $t$ is the thickness of the outside component.

In outside components of compression members:

a) The component's strength shall satisfy the requirements of Section E.2 with an effective length $kL = s/2$, where $s$ is the pitch, and

b) If multiple rows of fasteners are used, the component's strength shall satisfy the requirements of Section B.5.4.2 with a width $b = 0.8g$ where $g$ is the gage. If only one line of fasteners is used, the component's strength shall satisfy the requirements of Section B.5.4.1 with a width $b$ = the edge distance of the fastener.

## J.2 WELDS

The available strength ($\phi R_n$ for LRFD and $R_n / \Omega$ for ASD) of welds shall be determined using this Section where

$\phi = 0.75$ (LRFD)

$\Omega = 1.95$ (ASD)

### J.2.1 Groove Welds

### J.2.1.1 Complete Joint Penetration and Partial Joint Penetration Groove Welds

The following types of groove welds are complete joint penetration welds:

a) Welds welded from both sides with the root of the first weld backgouged to sound metal before welding the second side.

b) Welds welded from one side using permanent or temporary backing.

c) Welds welded from one side using AC-GTAW root pass without backing

d) Welds welded from one side using PAW-VP in the keyhole mode.

All other groove welds are partial joint penetration welds.

### J.2.1.2 Groove Weld Size

The size $S_w$ of a complete joint penetration groove weld is the thickness of the thinner part joined.

The size $S_w$ of a partial joint penetration groove weld is the depth of preparation for all J and U groove welds and for all V and bevel groove welds with an included angle greater than 45°.

### J.2.1.3 Groove Weld Effective Length

A groove weld's effective length $L_{we}$ for tension and compression is the length of the weld perpendicular to the direction of tensile or compressive stress. A groove weld's effective length for shear is the length of the weld parallel to the direction of shear stress.

### J.2.2 Fillet Welds

### J.2.2.1 Fillet Weld Size

The effective throat $S_{we}$ is the shortest distance from the joint root to the face of the diagrammatic weld.

The size of fillet welds shall be not less than the size required to transmit calculated forces or the size shown in Table J.2.1. These requirements do not apply to fillet weld reinforcements of groove welds.

**Table J.2.1**
**MINIMUM SIZE OF FILLET WELDS**

| Base Metal Thickness $t$ of Thicker Part Joined in. | Minimum Size of Fillet Weld in. | Base Metal Thickness $t$ of Thicker Part Joined mm | Minimum Size of Fillet Weld mm |
|---|---|---|---|
| $t \leq$ ¼ | 1/8 | $t \leq 6$ | 3 |
| ¼ < $t \leq$ ½ | 3/16 | $6 < t \leq 13$ | 5 |
| ½ < $t \leq$ ¾ | 1/4 | $13 < t \leq 20$ | 6 |
| $t >$ ¾ | 5/16 | $t > 20$ | 8 |

The maximum size of fillet welds shall be:

a) Along edges of material less than ¼ in. (6 mm) thick, not greater than the thickness of the material.

b) Along edges of material ¼ in. (6 mm) or more in thickness, no greater than the thickness of the material minus 1/16 in. (2 mm), unless the weld is especially designated on the drawings to be built out to obtain full-throat thickness. In the as-welded condition, the distance between the edge of the base metal and the toe of the weld is permitted to be less than 1/16 in. (2 mm) provided the weld size is clearly verifiable.

### J.2.2.2 Fillet Weld Effective Length

A fillet weld's effective length $L_{we}$ is the overall length of the weld, including boxing. If the effective length is less than four times its nominal size $S_w$, the effective weld size shall be considered to be 25% of its effective length.

The length of any segment of intermittent fillet welds shall not be less than the greater of four times the weld size and 1½ in. (40 mm).

The maximum effective length of an end-loaded fillet weld is $100S_w$.

### J.2.3 Plug and Slot Welds

The effective area $A_{we}$ of plug or slot welds is the nominal area of the hole or slot in the plane of the faying surface. Slot lengths shall not exceed 10 times the slotted material's thickness.

### J.2.4 Stud Welds

The base metal thickness for arc stud welding shall not be less than 50% of the stud diameter. The base metal thickness for capacitor discharge stud welding shall not be less than 25% of the stud diameter.

### J.2.5 Strength

The nominal strength $R_n$ of groove, fillet, plug, slot, and stud welded joints shall be the lesser of the base material strength for the limit states of tensile rupture and shear rupture and the weld metal strength for the limit state of rupture as follows:

a) For the base metal

$$R_n = F_{nBM} A_{BM} \qquad \text{(J.2-1)}$$

b) For the weld metal

$$R_n = F_{nw} A_{we} \qquad \text{(J.2-2)}$$

where

$F_{nBM}$ = nominal stress of the base metal corresponding to its welded ultimate strength from Table A.4.3 or Table A.4.3M
$F_{nw}$ = nominal stress of the weld metal corresponding to its ultimate strength from Table A.4.6
$A_{BM}$ = cross-sectional area of the base metal
$A_{we}$ = effective area of the weld

$F_{nBM}$ , $F_{nw}$ , $A_{BM}$, and $A_{we}$ are given in Table J.2.2.

## Table J.2.2
## NOMINAL STRENGTH OF WELDED JOINTS

| | Base Metal | | Weld Metal | |
|---|---|---|---|---|
| Load Type and Direction Relative to Weld Axis | Nominal Stress $F_{nBM}$ | Effective Area $A_{BM}$ | Nominal Stress $F_{nw}$ | Effective Area $A_{we}$ |
| **COMPLETE-JOINT PENETRATION GROOVE WELDS** | | | | |
| tension or compression normal to weld axis | $F_{tuw}$ | $S_wL_{we}$ | $F_{tuw}$ | $S_wL_{we}$ |
| tension or compression parallel to weld axis | tension or compression in parts parallel to a weld need not be considered in designing welds joining the parts | | | |
| shear | $0.6F_{tuw}$ | $S_wL_{we}$ | $0.6F_{tuw}$ | $S_wL_{we}$ |
| **PARTIAL-JOINT PENETRATION GROOVE WELDS** | | | | |
| tension or compression normal to weld axis | $F_{tuw}$ | $S_wL_{we}$ | $0.6F_{tuw}$ | $S_wL_{we}$ |
| tension or compression parallel to weld axis | tension or compression in parts parallel to a weld need not be considered in designing welds joining the parts | | | |
| shear | $0.6F_{tuw}$ | $S_wL_{we}$ | $0.6F_{tuw}$ | $S_wL_{we}$ |
| **FILLET WELDS** | | | | |
| shear | $0.6F_{tuw}$ | $S_wL_{we}$ | $0.6(0.85F_{tuw})$ (see note 1) | $S_{we}L_{we}$ |
| tension or compression parallel to weld axis | tension or compression in parts parallel to a weld need not be considered in designing welds joining the parts | | | |
| **PLUG AND SLOT WELDS** | | | | |
| shear parallel to faying surface | $0.6F_{tuw}$ | see J.2.3 | $0.6F_{tuw}$ | see J.2.3 |
| **STUD WELDS** | | | | |
| shear | $0.6F_{tuw}$ | $\pi D^2/4$ | $0.6F_{tuw}$ | $(\pi/4)(D-1.191/n)^2$ |
| tension | $F_{tuw}$ | $\pi D^2/4$ | $F_{tuw}$ | $(\pi/4)(D-1.191/n)^2$ |

① Alternately, the strength of fillet welds loaded transversely shall be taken as 1.36 times the strength given in Table J.2.2.
② $F_{tuw}$ for base metal is listed in Tables A.4.3 and A.4.3M.
③ $F_{tuw}$ for filler metal is listed in Table A.4.6.

### J.2.6 Combination of Welds

If two or more of the types of welds (groove, fillet, plug, or slot) are combined in a single joint, the strength of each shall be separately computed with respect to the axis of the group in order to determine the strength of the combination.

### J.2.7 Post-Weld Heat Treatment

The nominal strength of the weld-affected zone of post-weld-heat-treated base metal shall be taken as given in

### Table J.5.4
### HOLE DIAMETER FOR EQUATION J.5-10

| Screw Size | Screw Diameter *D* in. | Hole Diameter $D_h$ in. | Drill Size |
|---|---|---|---|
| 8 | 0.164 | 0.177 | 16 |
| 10 | 0.190 | 0.201 | 7 |
| 12 | 0.216 | 0.228 | 1 |
| ¼ | 0.250 | 0.266 | H |

b) The nominal strength $R_n$ for the limit state of pull-over for countersunk screws with an 82° nominal angle head is:

$$R_n = (0.27 + 1.45t_1/D)\, D\, t_1 F_{ty1} \qquad \text{(J.5-11)}$$

for 0.06 in. $\leq t_1 < 0.19$ in. (1.5 mm $\leq t_1 < 5$ mm) and $t_1/D \leq 1.1$. If $t_1/D > 1.1$, use $t_1/D = 1.1$

## J.5.4.3 Screw Tension

The nominal strength $R_n$ of an aluminum screw for the limit state of screw tensile rupture is:

$$R_n = A_r F_{tu}/1.25 \qquad \text{(J.5-12)}$$

where

$A_r$ = root area of the screw
$F_{tu}$ = tensile ultimate strength of the screw
= 68 ksi (470 MPa) for 7075-T73 screws
= 62 ksi (430 MPa) for 2024-T4 screws

## J.5.5 Screwed Connection Shear

The shear strength of a screwed connection is the least of the bearing, tilting, and screw shear rupture strengths. The available shear strength ($\phi R_n$ for LRFD and $R_n/\Omega$ for ASD) shall be determined as follows:

$\phi$ = 0.50 (LRFD)
$\Omega$ = 3.0 (ASD)

The nominal strength $R_n$ for the limit state of bearing shall be determined in accordance with Section J.5.5.1.

The nominal strength $R_n$ for the limit state of tilting shall be determined in accordance with Section J.5.5.2.

The nominal strength $R_n$ for the limit state of screw shear rupture shall be determined in accordance with Section J.5.5.3.

## J.5.5.1 Screw Bearing

The nominal strength $R_n$ for the limit state of bearing is

$$R_n = d_e\, t\, F_{tu} \leq 2DtF_{tu} \qquad \text{(J.5-13)}$$

where

$d_e$ = distance from the center of the screw to the edge of the part in the direction of force.
$t$ = for plain holes, nominal thickness of the connected part; for countersunk holes, nominal thickness of the connected part less ½ the countersink depth.
$F_{tu}$ = tensile ultimate strength of the connected part
$D$ = nominal diameter of the screw

## J.5.5.2 Screw Tilting

For $t_2 \leq t_1$, the nominal strength $R_n$ for the limit state of tilting is:

$$R_n = 4.2(t_2^3 D)^{1/2} F_{tu2} \qquad \text{(J.5-14)}$$

where

$t_1$ = nominal thickness of the part in contact with the screw head or washer
$t_2$ = nominal thickness of the part not in contact with the screw head or washer

For $t_2 > t_1$, tilting is not a limit state.

## J.5.5.3 Screw Shear

The nominal strength $R_n$ of an aluminum screw for the limit state of screw shear rupture is:

$$R_n = A_r F_{su}/1.25 \qquad \text{(J.5-15)}$$

where

$A_r$ = root area of the screw
$F_{su}$ = shear ultimate strength of the screw
= 41 ksi (285 MPa) for 7075-T73 screws
= 37 ksi (255 MPa) for 2024-T4 screws

# J.6 PINS

## J.6.1 Holes for Pins

The nominal diameter of holes for pins shall not be more than 1/32 in. (1 mm) greater than the nominal diameter of the pin.

## J.6.2 Minimum Edge Distance of Pins

The distance from the center of a pin to an edge of a part shall not be less than 1.5 times the nominal diameter of the pin. See Section J.6.5 for the effect of edge distance on bearing strength.

## J.6.3 Pin Tension

Pins shall not be used to resist loads acting parallel to the axis of the pin.

## J.6.4 Pin Shear and Flexure

The available strength ($\phi R_n$ for LRFD and $R_n/\Omega$ for ASD) of an aluminum pin in shear or flexure shall be determined as follows:

$M_m$ = mean value of the material factor, the ratio of the specimen's relevant material strength to the specified minimum strength. The relevant material strength shall be determined by conducting tensile tests in accordance with ASTM B557 on specimens taken from the component tested.

$n$ = number of tests

$R_{ti}$ = strength of $i$th test

$R_{tm}$ = mean strength of all tests $= \dfrac{\sum_{i=1}^{n} R_{ti}}{n}$

$V_F$ = coefficient of variation of the fabrication factor

$V_M$ = coefficient of variation of the material factor

$V_P$ = coefficient of variation of the ratio of the test strengths divided by the average value of all the test strengths

$$= \sqrt{\frac{\sum_{i=1}^{n}\left(\frac{R_{ti}}{R_{tm}}\right)^2 - \frac{\left(\sum_{i=1}^{n}\left(\frac{R_{ti}}{R_{tm}}\right)\right)^2}{n}}{n-1}}$$

$V_Q$ = coefficient of variation of the loads

$$= \frac{\sqrt{(0.105\alpha)^2 + 0.25^2}}{1.05\alpha + 1};$$

in lieu of calculation by the above formula, $V_Q = 0.21$

$\alpha$ = $D_n / L_n$ ; in lieu of calculation, $\alpha = 0.2$

$\beta o$ = the target reliability index

= 2.5 for columns, beams and beam-columns,

= 3.0 for tension members, and

= 3.5 for connections.

The following values shall be used when data established from a sufficient number of results on material properties do not exist for the member or connection:

$M_m$ = 1.10 for behavior governed by yield

= 1.00 for behavior governed by rupture

$F_m$ = 1.00

$V_M$ = 0.06

$V_F$ = 0.05 for structural members and mechanically fastened connections

= 0.15 for welded connections

## 1.4 TESTING ROOFING AND SIDING

The flexural strength of roofing and siding shall be established from tests when any of the following conditions apply.

a) Web angles are asymmetrical about the centerline of a valley, rib, flute, crimp, or other corrugation;

b) Web angles are less than 45°;

c) Aluminum panels are alternated with panels composed of any material having significantly different strengths or deflection characteristics;

d) Flats spanning from rib to rib or other corrugation in the transverse direction have a width to thickness ratio greater than either of the following

(1) $\dfrac{1230}{\sqrt[3]{q}}$ where $q$ is the design load in psf ( $\dfrac{447}{\sqrt[3]{q}}$ where $q$ is the design load in kN/m$^2$)

(2) $435\sqrt{\dfrac{F_{ty}}{q}}$ where $F_{ty}$ is in ksi and $q$ is in psf ( $37\sqrt{\dfrac{F_{ty}}{q}}$ where $F_{ty}$ is in MPa and $q$ is in kN/m$^2$);

e) Panel ribs, valleys, crimps, or other corrugations are of unequal depths;

f) Specifications prescribe less than one fastener per rib to resist negative or uplift loading at each purlin, girt, or other transverse supporting member; or

g) Panels are attached to supporting members by profile interlocking straps or clips.

### 1.4.1 Test Method

Tests shall be conducted in accordance with ASTM E 1592.

### 1.4.2 Different Thicknesses

Only the thinnest and thickest specimens manufactured are required to be tested when panels are of like configuration, differing only in material thickness. Where the failure of the test specimens is from flexural stress, the flexural strength for intermediate thicknesses shall be interpolated as follows:

$$\log M_i = \log M_1 + \left(\frac{\log t_i - \log t_{\min}}{\log t_{\max} - \log t_{\min}}\right)\left(\log M_2 - \log M_1\right) \tag{1.4-1}$$

where

$M_i$ = flexural strength of member of intermediate thickness $t_i$

$M_1$ = flexural strength of member of thinnest material

$M_2$ = flexural strength of member of thickest material

$t_i$ = thickness of intermediate thickness material

$t_{min}$ = thickness of thinnest material tested

$t_{max}$ = thickness of thickest material tested

### 1.4.3 Available Strengths

Available strengths shall be determined using the resistance factors for LRFD and safety factors for ASD given in Chapter F for flexure and those in Chapter J applied to the minimum test strength achieved for fasteners.

### 1.4.4 Deflections

Deflections shall meet the requirements of Section L.3.

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# Table 2-23

## ALLOWABLE STRESSES $F/\Omega$ FOR BUILDING-TYPE STRUCTURES (UNWELDED)

**6351 - T6** **ASTM B221 0.000 to 0.749 in. thick**

$F_{ty}$ = 37 k/in$^2$
$F_{cy}$ = 37 k/in$^2$
$F_{tu}$ = 42 k/in$^2$
$E$ = 10,100 k/in$^2$
$k_t$ = 1

| **Allowable Stresses** $F/\Omega$ (k/in$^2$) | Section | $F/\Omega$ |
|---|---|---|
| Axial Tension | | |
| axial tension stress on net effective area | D.2b | 21.5 |
| axial tension stress on gross area | D.2a | 22.4 |
| Shear or torsion | | |
| Shear or torsion rupture | G, H.2 | 12.9 |
| Bearing | | |
| bolts or rivets on holes | J.3.6a, J.4.6 | 43.1 |
| bolts on slots, pins on holes, flat surfaces | J.3.6b, J.6.5, J.8 | 28.6 |
| screws in holes | J.5.5.1 | 28.0 |

| | | Slenderness $\lambda$ | $F/\Omega$ for $\lambda \le \lambda_1$ | $\lambda_1$ | $F/\Omega$ for $\lambda_1 < \lambda < \lambda_2$ | $\lambda_2$ | $F/\Omega$ for $\lambda \ge \lambda_2$ |
|---|---|---|---|---|---|---|---|
| Axial Compression | | | | | | | |
| member buckling | E.2 | $kL/r$ | 22.4 | 17.7 | $0.00053\lambda^2 - 0.254\lambda + 26.8$ | 64 | $51{,}352/\lambda^2$ |
| Flexure | | | | | | | |
| lateral-torsional buckling | F.4 | see F.4.2 | | - | see F.4 | 64 | $60{,}414/\lambda^2$ |
| Elements - Uniform Compression | | | | | | | |
| flat elements supported on one edge in columns whose buckling axis is not an axis of symmetry | B.5.4.1 | $b/t$ | 22.4 | 6.6 | $29.0 - 0.996\lambda$ | 12 | $2{,}417/\lambda^2$ |
| flat elements supported on one edge in all other columns and all beams | B.5.4.1 | $b/t$ | 22.4 | 6.6 | $29.0 - 0.996\lambda$ | 10.2 | $191/\lambda$ |
| flat elements supported on both edges | B.5.4.2 | $b/t$ | 22.4 | 20.5 | $29.0 - 0.319\lambda$ | 32 | $597/\lambda$ |
| flat elements supported on both edges and with an intermediate stiffener | B.5.4.4 | $\lambda_s$ | 22.4 | 17.7 | $25.3 - 0.163\lambda$ | 64 | $60{,}414/\lambda^2$ |
| round hollow elements | B.5.4.5 | $(R_b/t)^{1/2}$ | 22.4 | 5.2 | $27.7 - 1.020\lambda$ | 11.6 | $3{,}776/[\lambda^2(1+\lambda/35)^2]$ |
| flat elements - direct strength method | B.5.4.6 | $\lambda_{eq}$ | 22.4 | 32.8 | $29.0 - 0.199\lambda$ | 51 | $956/\lambda$ |
| Elements - Flexural Compression | | | | | | | |
| flat elements supported on both edges | B.5.5.1 | $b/t$ | 33.6 | 32.8 | $43.1 - 0.288\lambda$ | 75 | $1{,}611/\lambda$ |
| flat elements supported on tension edge, compression edge free | B.5.5.2 | $b/t$ | 33.6 | 6.1 | $43.1 - 1.549\lambda$ | 19 | $4{,}932/\lambda^2$ |
| flat elements supported on both edges and with a longitudinal stiffener | B.5.5.3 | $b/t$ | 33.6 | 73.5 | $43.1 - 0.128\lambda$ | 168 | $3{,}612/\lambda$ |
| round hollow elements | B.5.5.4 | $(R_b/t)^{1/2}$ | $41.6 - 2.92\lambda$ | 7.3 | $27.7 - 1.020\lambda$ | 11.6 | $3{,}776/[\lambda^2(1+\lambda/35)^2]$ |
| flat elements - direct strength method | B.5.5.5 | $\lambda_{eq}$ | 33.6 | 21.3 | $43.1 - 0.442\lambda$ | 49 | $1{,}047/\lambda$ |
| Elements - Shear | | | | | | | |
| flat elements supported on both edges | G.2 | $b/t$ | 13.5 | 34.7 | $17.5 - 0.117\lambda$ | 61 | $38{,}665/\lambda^2$ |
| flat elements supported on one edge | G.3 | $b/t$ | 13.5 | 14.5 | $17.5 - 0.281\lambda$ | 26 | $6{,}713/\lambda^2$ |
| pipes and round or oval tubes | G.4 | $2.9(R_b/t)^{5/8}(L_v/R_b)^{1/4}$ | 13.5 | 61.0 | $22.8 - 0.153\lambda$ | 61 | $50{,}264/\lambda^2$ |
| Torsion | | | | | | | |
| pipes and round or oval tubes | H.2.1 | $2.9(R_b/t)^{5/8}(L_s/R_b)^{1/4}$ | 13.5 | 34.7 | $17.5 - 0.117\lambda$ | 61 | $38{,}665/\lambda^2$ |

# Table 2-24

## ALLOWABLE STRESSES $F/\Omega$ FOR BUILDING-TYPE STRUCTURES (UNWELDED)

**7005 - T53** **ASTM B221 0.000 to 0.750 in. thick**

$F_{ty}$ = 44 k/in$^2$
$F_{cy}$ = 44 k/in$^2$
$F_{tu}$ = 50 k/in$^2$

$E$ = 10,100 k/in$^2$
$k_t$ = 1

| **Allowable Stresses** $F/\Omega$ (k/in$^2$) | Section | $F/\Omega$ |
|---|---|---|
| Axial Tension | | |
| axial tension stress on net effective area | D.2b | 25.6 |
| axial tension stress on gross area | D.2a | 26.7 |
| Shear or torsion | | |
| Shear or torsion rupture | G, H.2 | 15.4 |
| Bearing | | |
| bolts or rivets on holes | J.3.6a, J.4.6 | 51.3 |
| bolts on slots, pins on holes, flat surfaces | J.3.6b, J.6.5, J.8 | 34.1 |
| screws in holes | J.5.5.1 | 33.3 |

| | | Slenderness $\lambda$ | $F/\Omega$ for $\lambda \le \lambda_1$ | $\lambda_1$ | $F/\Omega$ for $\lambda_1 < \lambda < \lambda_2$ | $\lambda_2$ | $F/\Omega$ for $\lambda \ge \lambda_2$ |
|---|---|---|---|---|---|---|---|
| Axial Compression | | | | | | | |
| member buckling | E.2 | $kL/r$ | 26.7 | 17.4 | $0.00079\ \lambda^2 - 0.340\ \lambda + 32.3$ | 58 | $51,352\ /\lambda^2$ |
| Flexure | | | | | | | |
| lateral-torsional buckling | F.4 | see F.4.2 | | - | see F.4 | 58 | $60,414\ /\lambda^2$ |
| Elements - Uniform Compression | | | | | | | |
| flat elements supported on one edge in columns whose buckling axis is not an axis of symmetry | B.5.4.1 | $b/t$ | 26.7 | 6.2 | $34.9 - 1.317\ \lambda$ | 11 | $2,417\ /\lambda^2$ |
| flat elements supported on one edge in all other columns and all beams | B.5.4.1 | $b/t$ | 26.7 | 6.2 | $34.9 - 1.317\ \lambda$ | 9.3 | $210\ /\lambda$ |
| flat elements supported on both edges | B.5.4.2 | $b/t$ | 26.7 | 19.5 | $34.9 - 0.421\ \lambda$ | 29 | $656\ /\lambda$ |
| flat elements supported on both edges and with an intermediate stiffener | B.5.4.4 | $\lambda_s$ | 26.7 | 17.4 | $30.4 - 0.214\ \lambda$ | 58 | $60,414\ /\lambda^2$ |
| round hollow elements | B.5.4.5 | $(R_b/t)^{1/2}$ | 26.7 | 5.0 | $33.2 - 1.296\ \lambda$ | 10.7 | $3,776\ /[\lambda^2(1+\lambda/35)^2]$ |
| flat elements - direct strength method | B.5.4.6 | $\lambda_{eq}$ | 26.7 | 31.2 | $34.9 - 0.263\ \lambda$ | 46 | $1,049\ /\lambda$ |
| Elements - Flexural Compression | | | | | | | |
| flat elements supported on both edges | B.5.5.1 | $b/t$ | 40.0 | 31.8 | $52.2 - 0.384\ \lambda$ | 68 | $1,774\ /\lambda$ |
| flat elements supported on tension edge, compression edge free | B.5.5.2 | $b/t$ | 40.0 | 5.9 | $52.2 - 2.066\ \lambda$ | 17 | $4,932\ /\lambda^2$ |
| flat elements supported on both edges and with a longitudinal stiffener | B.5.5.3 | $b/t$ | 40.0 | 71.3 | $52.2 - 0.171\ \lambda$ | 152 | $3,976\ /\lambda$ |
| round hollow elements | B.5.5.4 | $(R_b/t)^{1/2}$ | $49.8 - 3.71\ \lambda$ | 6.9 | $33.2 - 1.296\ \lambda$ | 10.7 | $3,776\ /[\lambda^2(1+\lambda/35)^2]$ |
| flat elements - direct strength method | B.5.5.5 | $\lambda_{eq}$ | 40.0 | 20.7 | $52.2 - 0.590\ \lambda$ | 44 | $1,153\ /\lambda$ |
| Elements - Shear | | | | | | | |
| flat elements supported on both edges | G.2 | $b/t$ | 16.0 | 33.1 | $21.1 - 0.155\ \lambda$ | 56 | $38,665\ /\lambda^2$ |
| flat elements supported on one edge | G.3 | $b/t$ | 16.0 | 13.8 | $21.1 - 0.372\ \lambda$ | 23 | $6,713\ /\lambda^2$ |
| pipes and round or oval tubes | G.4 | $2.9(R_b/t)^{5/8}(L_v/R_b)^{1/4}$ | 16.0 | 56.7 | $27.5 - 0.202\ \lambda$ | 56 | $50,264\ /\lambda^2$ |
| Torsion | | | | | | | |
| pipes and round or oval tubes | H.2.1 | $2.9(R_b/t)^{5/8}(L_s/R_b)^{1/4}$ | 16.0 | 33.1 | $21.1 - 0.155\ \lambda$ | 56 | $38,665\ /\lambda^2$ |

## Table 4-7

## DEFLECTIONS AND ALLOWABLE LOADS FOR 6063-T6 ALUMINUM BAR GRATING

Type P-19
bearing bar spacing 1 3/16in. cross bar spacing 4in.

| Bearing Bar |  |  |  |  | Span (in.) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| depth | thickness | $L_{max}$ |  |  | 24 | 30 | 36 | 42 | 48 | 54 | 60 | 66 | 72 | 78 | 84 | 90 | 96 | 102 | 108 |
| λ | 20.6 |  | $D_c$ | in. | 0.117 | 0.183 | 0.264 | 0.359 | 0.469 | 0.594 | 0.733 | 0.887 | 1.056 | 1.239 | 1.437 |  |  |  |  |
| 1.5 | 0.125 | 53 | $U$ | lb/ft$^2$ | 1193 | 764 | 530 | 390 | 298 | 236 | 191 | 158 | 133 | 113 | 97 | 85 | 75 | 66 | 59 |
| I/bar | 0.0352 |  | $D_u$ | in. | 0.122 | 0.191 | 0.275 | 0.374 | 0.489 | 0.619 | 0.764 | 0.924 | 1.100 | 1.291 | 1.497 | 1.719 | 1.955 | 2.207 | 2.475 |
| I/ft | 0.3516 |  | $C$ | lb/ft | 1193 | 955 | 796 | 682 | 597 | 530 | 477 | 434 | 398 | 367 | 341 | 318 | 298 | 281 | 265 |
| λ | 45.1 |  | $D_c$ | in. | 0.098 | 0.153 | 0.220 | 0.299 | 0.391 | 0.495 | 0.611 | 0.739 | 0.880 | 1.033 | 1.198 | 1.375 | 1.564 | 1.766 | 1.980 |
| 1.5 | 0.1875 | 59 | $U$ | lb/ft$^2$ | 1790 | 1146 | 796 | 585 | 448 | 354 | 286 | 237 | 199 | 169 | 146 | 127 | 112 | 99 | 88 |
| I/bar | 0.0527 |  | $D_u$ | in. | 0.122 | 0.191 | 0.275 | 0.374 | 0.489 | 0.619 | 0.764 | 0.924 | 1.100 | 1.291 | 1.497 | 1.719 | 1.955 | 2.207 | 2.475 |
| I/ft | 0.5273 |  | $C$ | lb/ft | 1790 | 1432 | 1193 | 1023 | 895 | 796 | 716 | 651 | 597 | 551 | 511 | 477 | 448 | 421 | 398 |
| λ | 30.0 |  | $D_c$ | in. | 0.098 | 0.153 | 0.220 | 0.299 | 0.391 | 0.495 | 0.611 | 0.739 | 0.880 | 1.033 | 1.198 | 1.375 | 1.564 | 1.766 | 1.980 |
| 1.5 | 0.25 | 63 | $U$ | lb/ft$^2$ | 2387 | 1528 | 1061 | 779 | 597 | 471 | 382 | 316 | 265 | 226 | 195 | 170 | 149 | 132 | 118 |
| I/bar | 0.0703 |  | $D_u$ | in. | 0.122 | 0.191 | 0.275 | 0.374 | 0.489 | 0.619 | 0.764 | 0.924 | 1.100 | 1.291 | 1.497 | 1.719 | 1.955 | 2.207 | 2.475 |
| I/ft | 0.7031 |  | $C$ | lb/ft | 2387 | 1909 | 1591 | 1364 | 1193 | 1061 | 955 | 868 | 796 | 734 | 682 | 636 | 597 | 562 | 530 |
| λ | 22.5 |  | $D_c$ | in. | 0.098 | 0.153 | 0.220 | 0.299 | 0.391 | 0.495 | 0.611 | 0.739 | 0.880 | 1.033 | 1.198 | 1.375 | 1.564 | 1.766 | 1.980 |
| 1.75 | 0.1875 | 66 | $U$ | lb/ft$^2$ | 2437 | 1559 | 1083 | 796 | 609 | 481 | 390 | 322 | 271 | 231 | 199 | 173 | 152 | 135 | 120 |
| I/bar | 0.0837 |  | $D_u$ | in. | 0.105 | 0.164 | 0.236 | 0.321 | 0.419 | 0.530 | 0.655 | 0.792 | 0.943 | 1.106 | 1.283 | 1.473 | 1.676 | 1.892 | 2.121 |
| I/ft | 0.8374 |  | $C$ | lb/ft | 2437 | 1949 | 1624 | 1392 | 1218 | 1083 | 975 | 886 | 812 | 750 | 696 | 650 | 609 | 573 | 541 |
| λ | 32.5 |  | $D_c$ | in. | 0.084 | 0.131 | 0.189 | 0.257 | 0.335 | 0.424 | 0.524 | 0.634 | 0.754 | 0.885 | 1.027 | 1.178 | 1.341 | 1.514 | 1.697 |
| 1.75 | 0.25 | 71 | $U$ | lb/ft$^2$ | 3249 | 2079 | 1444 | 1061 | 812 | 642 | 520 | 430 | 361 | 308 | 265 | 231 | 203 | 180 | 160 |
| I/bar | 0.1117 |  | $D_u$ | in. | 0.105 | 0.164 | 0.236 | 0.321 | 0.419 | 0.530 | 0.655 | 0.792 | 0.943 | 1.106 | 1.283 | 1.473 | 1.676 | 1.892 | 2.121 |
| I/ft | 1.1165 |  | $C$ | lb/ft | 3249 | 2599 | 2166 | 1856 | 1624 | 1444 | 1300 | 1181 | 1083 | 1000 | 928 | 866 | 812 | 764 | 722 |
| λ | 24.3 |  | $D_c$ | in. | 0.084 | 0.131 | 0.189 | 0.257 | 0.335 | 0.424 | 0.524 | 0.634 | 0.754 | 0.885 | 1.027 | 1.178 | 1.341 | 1.514 | 1.697 |
| 2 | 0.1875 | 73 | $U$ | lb/ft$^2$ | 3182 | 2037 | 1414 | 1039 | 796 | 629 | 509 | 421 | 354 | 301 | 260 | 226 | 199 | 176 | 157 |
| I/bar | 0.1250 |  | $D_u$ | in. | 0.092 | 0.143 | 0.206 | 0.281 | 0.367 | 0.464 | 0.573 | 0.693 | 0.825 | 0.968 | 1.123 | 1.289 | 1.466 | 1.656 | 1.856 |
| I/ft | 1.2500 |  | $C$ | lb/ft | 3182 | 2546 | 2122 | 1819 | 1591 | 1414 | 1273 | 1157 | 1061 | 979 | 909 | 849 | 796 | 749 | 707 |