3.4.10 Uniform Compression in Elements of Columns—Curved Elements Supported on Both Edges

a. $F_c = \dfrac{F_{cy}}{n_y}$ *(Eq. 3.4.10-1)*

for $R_b/t \le S_1$

b. $F_c = \dfrac{1}{n_u}\left[B_t - D_t\sqrt{\dfrac{R_b}{t}}\right]$ *(Eq. 3.4.10-2)*

for $S_1 < R_b/t < S_2$

c. $F_c = \dfrac{\pi^2 E}{16 n_u \left(\dfrac{R_b}{t}\right)\left(1 + \dfrac{\sqrt{R_b/t}}{35}\right)^2}$ *(Eq. 3.4.10-3)*

for $R_b/t \ge S_2$

where

$S_1 = \left(\dfrac{B_t - \dfrac{n_u}{n_y}F_{cy}}{D_t}\right)^2$ *(Eq. 3.4.10-4)*

$S_2 = C_t$ *(Eq. 3.4.10-5)*

For tubes with circumferential welds, the equations of this Section apply for $R_b/t \le 20$.

3.4.11 Compression in Beams, Extreme Fiber, Gross Section—Single Web Shapes

For single web shapes not subject to lateral buckling (bent about the strong axis with continuous lateral support or bent about the weak axis), determine the compressive allowable stress F_c from Sections 3.4.15 through 3.4.19 as applicable.

For single web shapes subject to lateral buckling (bent about the strong axis without continuous lateral support), the compressive allowable stress F_c is the lesser of that determined from Sections 3.4.15 through 3.4.19 as applicable and the following:

a. $F_c = \dfrac{F_{cy}}{n_y}$ *(Eq. 3.4.11-1)*

for $\dfrac{L_b}{r_y\sqrt{C_b}} \le S_1$

b. $F_c = \dfrac{\left(B_c - \dfrac{D_c L_b}{1.2 r_y \sqrt{C_b}}\right)}{n_y}$ *(Eq. 3.4.11-2)*

for $S_1 < \dfrac{L_b}{r_y\sqrt{C_b}} < S_2$

c. $F_c = \dfrac{C_b \pi^2 E}{n_y\left(\dfrac{L_b}{1.2 r_y}\right)^2}$ *(Eq. 3.4.11-3)*

for $\dfrac{L_b}{r_y\sqrt{C_b}} \ge S_2$

where

$S_1 = \dfrac{1.2\,(B_c - F_{cy})}{D_c}$ *(Eq. 3.4.11-4)*

$S_2 = 1.2 C_c$ *(Eq. 3.4.11-5)*

r_y = radius of gyration of the shape (about an axis parallel to the web) (For beams that are unsymmetrical about the horizontal axis, r_y shall be calculated as though both flanges were the same as the compression flange).

L_b = length of the beam between bracing points or between a brace point and the free end of a cantilever beam. Bracing points are the points at which the compression flange is restrained against lateral movement or the cross section is restrained against twisting.

C_b = coefficient that depends on moment variation over the unbraced length. C_b shall be as given in Section 4.9.4 or taken as 1.

Alternatively, F_c may be calculated by replacing r_y by r_{ye} given in Section 4.9.

3.4.12 Compression in Beams, Extreme Fiber, Gross Section—Round or Oval Tubes

a. $F_c = \dfrac{1.17 F_{cy}}{n_y}$ *(Eq. 3.4.12-1)*

for $R_b/t \le S_1$

b. $F_c = \dfrac{1}{n_y}\left(B_{tb} - D_{tb}\sqrt{\dfrac{R_b}{t}}\right)$ *(Eq. 3.4.12-2)*

for $S_1 < R_b/t < S_2$

c. For $R_b/t \ge S_2$, the allowable bending stress shall be determined from the formulas for tubes in compression in Section 3.4.10 using the formula that is appropriate for the particular value of R_b/t.

In the above equations

R_b = mid-thickness radius of a round element or maximum mid-thickness radius of an oval element

$S_1 = \left(\dfrac{B_{tb} - 1.17 F_{cy}}{D_{tb}}\right)^2$ *(Eq. 3.4.12-3)*

$S_2 = \left(\dfrac{\dfrac{n_u}{n_y}B_{tb} - B_t}{\dfrac{n_u}{n_y}D_{tb} - D_t}\right)^2$ *(Eq. 3.4.12-4)*

For tubes with circumferential welds, the equations of this Section apply for $R_b/t \le 20$.

3.4.13 Compression in Beams, Extreme Fiber, Gross Section—Solid Rectangular and Round Sections

For rectangular sections bent about the weak axis, rod, and square bar: $F_c = \dfrac{1.3 F_{cy}}{n_y}$

For rectangular sections bent about the strong axis:

a. $F_c = \dfrac{1.3 F_{cy}}{n_y}$ *(Eq. 3.4.13-1)*

for $\dfrac{d}{t}\sqrt{\dfrac{L_b}{C_b d}} \le S_1$

3.4.16 Uniform Compression in Elements of Beams—Flat Elements Supported on Both Edges

a. $F_c = \frac{F_{cy}}{n_y}$ *(Eq. 3.4.16-1)*

for $b/t \le S_1$

b. $F_c = \frac{1}{n_y}\left[B_p - 1.6D_p\frac{b}{t}\right]$ *(Eq. 3.4.16-2)*

for $S_1 < b/t < S_2$

c. $F_c = \frac{k_2\sqrt{B_pE}}{n_y(1.6b/t)}$ *(Eq. 3.4.16-3)*

for $b/t \ge S_2$

where

$S_1 = \frac{B_p - F_{cy}}{1.6D_p}$ *(Eq. 3.4.16-4)*

$S_2 = \frac{k_1B_p}{1.6D_p}$ *(Eq. 3.4.16-5)*

b = distance from unsupported edge of element to toe of the fillet or bend, except if the inside corner radius exceeds 4 times the thickness; then the inside radius shall be assumed equal to 4 times the thickness in calculating b. Element width b is illustrated in Figure 3.4.9-1.

3.4.16.1 Uniform Compression in Elements of Beams—Curved Elements Supported on Both Edges

a. $F_c = \frac{1.17F_{cy}}{n_y}$ *(Eq. 3.4.16.1-1)*

for $R_b/t \le S_1$

b. $F_c = \frac{1}{n_y}\left[B_t - D_t\sqrt{\frac{R_b}{t}}\right]$ *(Eq. 3.4.16.1-2)*

for $S_1 < R_b/t < S_2$

c. $F_c = \frac{\pi^2E}{16n_y\left(\frac{R_b}{t}\right)\left(1 + \frac{\sqrt{R_b/t}}{35}\right)^2}$ *(Eq. 3.4.16.1-3)*

for $R_b/t \ge S_2$

where

$S_1 = \left(\frac{B_t - 1.17F_{cy}}{D_t}\right)^2$ *(Eq. 3.4.16.1-4)*

$S_2 = C_t$ *(Eq. 3.4.16.1-5)*

C_t shall be determined using a plot of the curves of allowable stress for values of R_b/t less than and greater than S_2 or by a trial and error solution.

For tubes with circumferential welds, the equations of this Section apply for $R_b/t \le 20$.

3.4.16.2 Uniform Compression in Elements of Beams—Flat Elements Supported on One Edge and With Stiffener on Other Edge

The provisions of this Section apply when $D_s/b \le 0.8$. The allowable stress is the lesser of

$F_c = \frac{F_{cy}}{n_y}$ *(Eq. 3.4.16.2-1)*

and

$F_c = F_{UT} + (F_{ST} - F_{UT})\,\rho_{ST} \le F_{ST}$ *(Eq. 3.4.16.2-2)*

For a straight stiffener of constant thickness, F_c shall not exceed the allowable stress for the stiffener according to Section 3.4.8.

In the above equations

D_s = defined in Figure 3.4.9.1-1 and -2

F_{UT} = allowable stress according to Section 3.4.15 neglecting the stiffener

F_{ST} = allowable stress according to Section 3.4.16

ρ_{ST} = ratio to be determined as follows:

ρ_{ST} = 1.0 for $b/t \le S/3$

$\rho_{ST} = \frac{r_s}{9t\left(\frac{b/t}{S} - \frac{1}{3}\right)} \le 1.0$ for $S/3 < b/t \le S$

$\rho_{ST} = \frac{r_s}{1.5t\left(\frac{b/t}{S} + 3\right)} \le 1.0$ for $2S > b/t > S$

r_s = radius of gyration of the stiffener determined as follows:

- For simple straight lip stiffeners of constant thickness similar to that shown in Figure 3.4.9.1-1, r_s shall be calculated as:

  $r_s = \frac{d_s \sin\theta}{\sqrt{3}}$

- for other type stiffeners, r_s shall be calculated about the mid-thickness of the element being stiffened

d_s = flat width of stiffener shown in Figure 3.4.9.1-1

$S = 1.28\sqrt{\frac{E}{F_{cy}}}$

b = distance from unsupported edge of element to toe of fillet or bend, unless the inside corner radius exceeds $4t$; then the inside radius shall be assumed to be $4t$ to calculate b. Element width b is illustrated in Figure 3.4.9.1-1.

3.4.16.3 Uniform Compression in Elements of Beams—Flat Elements Supported on Both Edges and With an Intermediate Stiffener

a. $F_c = \frac{F_{cy}}{n_y}$ *(Eq. 3.4.16.3-1)*

for $\lambda_s \le S_1$

b. $F_c = \frac{(B_c - D_c\lambda_s)}{n_y}$ *(Eq. 3.4.16.3-2)*

for $S_1 < \lambda_s < S_2$

c. $F_c = \frac{\pi^2E}{n_y\lambda_s^2}$ *(Eq. 3.4.16.3-3)*

for $\lambda_s \ge S_2$

Table 6M
TYPICAL MECHANICAL PROPERTIES ① ② (Continued)

ALLOY AND TEMPER	TENSION				HARDNESS	SHEAR	FATIGUE	MODULUS
	STRENGTH MPa		ELONGATION percent in 2 in.		BRINNELL NUMBER	ULTIMATE SHEARING STRENGTH	ENDURANCE ③ LIMIT	MODULUS ④ OF ELASTICITY MPa × 10³
			in 50 mm	in 5D				
	ULTIMATE	YIELD	1.60 mm Thick Specimen	12.5 mm Diameter Specimen	500 kgf load 10 mm ball	MPa	MPa	
5154-O	240	115	27	. .	58	150	115	70
5154-H32	270	205	15	. .	67	150	125	70
5154-H34	290	230	13	. .	73	165	130	70
5154-H36	310	250	12	. .	78	180	140	70
5154-H38	330	270	10	. .	80	195	145	70
5154-H112	240	115	25	. .	63	. .	115	70
5252-H25	235	170	11	. .	68	145	. .	69
5252-H38, H28	285	240	5	. .	75	160	. .	69
5254-O	240	115	27	. .	58	150	115	70
5254-H32	270	205	15	. .	67	150	125	70
5254-H34	290	230	13	. .	73	165	130	70
5254-H36	310	250	12	. .	78	180	140	70
5254-H38	330	270	10	. .	80	195	145	70
5254-H112	240	115	25	. .	63	. .	115	70
5454-O	250	115	22	. .	62	160	. .	70
5454-H32	275	205	10	. .	73	165	. .	70
5454-H34	305	240	10	. .	81	180	. .	70
5454-H111	260	180	14	. .	70	160	. .	70
5454-H112	250	125	18	. .	62	160	. .	70
5456-O	310	160	. .	22	. .	. .	. .	71
5456-H25	310	165	. .	20	. .	. .	. .	71
5456-H321, H116	350	255	. .	14	90	205	. .	71
5457-O	130	50	22	. .	32	85	. .	69
5457-H25	180	160	12	. .	48	110	. .	69
5457-H38, H28	205	185	6	. .	55	125	. .	69
5652-O	195	90	25	27	47	125	110	70
5652-H32	230	195	12	16	60	140	115	70
5652-H34	260	215	10	12	68	145	125	70
5652-H36	275	240	8	9	73	160	130	70
5652-H38	290	255	7	7	77	165	140	70
5657-H25	160	140	12	. .	40	95	. .	69
5657-H38, H28	195	165	7	. .	50	105	. .	69
6061-O	125	55	25	27	30	85	60	69
6061-T4, T451	240	145	22	22	65	165	95	69
6061-T6, T651	310	275	12	15	95	205	95	69
Alclad 6061-O	115	50	25	. .	. .	75	. .	69
Alclad 6061-T4, T451	230	130	22	. .	. .	150	. .	69
Alclad 6061-T6, T651	290	255	12	. .	. .	185	. .	69
6063-O	90	50	. .	. .	25	70	55	69
6063-T1	150	90	20	. .	42	95	60	69
6063-T4	170	90	22	. .	. .	. .	. .	69
6063-T5	185	145	12	. .	60	115	70	69
6063-T6	240	215	12	. .	73	150	70	69
6063-T83	255	240	9	. .	82	150	. .	69
6063-T831	205	185	10	. .	70	125	. .	69
6063-T832	290	270	12	. .	95	185	. .	69
6066-O	150	85	. .	16	43	95	. .	69
6066-T4, T451	360	205	. .	16	90	200	. .	69
6066-T6. T651	395	360	. .	10	120	235	110	69
6070-T6	380	350	10	. .	. .	235	95	69
6101-H111	95	75	. .	. .	. .	. .	. .	69
6101-T6	220	195	15 ⑧	. .	71	140	. .	69
6262-T9	400	380	. .	9	120	240	90	69
6351-T4	250	150	20	. .	. .	. .	. .	69
6351-T6	310	285	14	. .	95	200	90	69
6463-T1	150	90	20	. .	42	95	70	69
6463-T5	185	145	12	. .	60	115	70	69
6463-T6	240	215	12	. .	74	150	70	69

For all numbered footnotes, see last page of this Table.

Example 30
DESIGN OF A SCREW CONNECTION
Illustrating Section 5.4

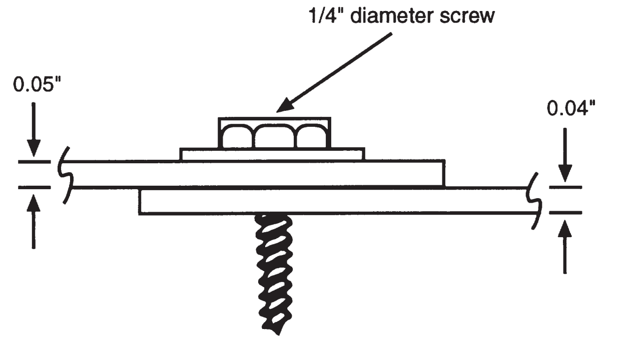

Figure 30

GIVEN:

1. Tapping screw of 7075-T73 aluminum, 1/4” diameter, UNC thread joining 0.05 in. thick 3003-H16 sheet to 0.04 in. thick 5052-H32 sheet.
2. 5/8” outside diameter flatwasher under the screw head.

REQUIRED:

The allowable shear and tension forces for the connection.

SOLUTION:

1. Allowable shear force

The allowable connection shear is determined according to *Specification* Section 5.4.3. F_{tu} is from Table 3.3-1.

Sheet	Alloy	Thickness	F_{tu}	$2F_{tu}Dt/n_u$
1	3003-H16	0.05	24	310 lb
2	5052-H32	0.04	31	320 lb

Since $t_2 = 0.04 < 0.05 = t_1$,

$4.2\ (t_2^3 D)^{1/2} F_{tu2}\ /n_s$

$4.2\ (0.04^3 \times 0.25)^{1/2}(31)/3 = 0.17$ kips = 170 lb

The smallest of (310, 320, and 170) is

170 lb = allowable shear

Also per Section 5.4.3, shear in screws:

The ultimate shear capacity of the screw: Since threads are in the shear plane, the effective shear area is calculated from the root diameter. The root diameter is given in Part VII, Table 5-3 as 0.1876 in.

effective shear area = $(\pi/4)(0.1876\text{ in.})^2 = 0.0276\text{ in}^2$

From *Specification* Table 5.2.3-1, the ultimate shear strength of 7075-T73 is 41 ksi, so

ultimate shear capacity = P_{ns} =

$$(41\text{ ksi})\ (0.0276\text{ in}^2) = 1.1\text{ kips} = 1100\text{ lb}$$

$P_{ns}/(1.25\ n_s) = (1100\text{ lb})/(1.25(3)) = 290$ lb

so use 170 lb as the allowable shear.

2. Allowable tensile force
   Specification Section 5.4.2 requires that the washer outside diameter D_w equal or exceed 5/16 in.:

$D_w = 5/8 > 5/16$

The allowable pull-out force, P_{not}/n_s, per Section 5.4.2.1 is:

$P_{not}/n_s = K_s D t_c F_{ty2}/3$

$= (1.01)(0.25)(0.04)(23)/3 = 0.077$ kips = 77 lb

The allowable pull-over force, P_{nov}/n_s, per Section 5.4.2.2 is:

$P_{nov}/n_s = C t_1 F_{tu1}(D_{ws} - D_h)/3$

$= (1.0)(0.05)(24)(0.625 - 0.25)/3$

$= 0.15$ kips = 150 lb

The ultimate tensile capacity of the screw is:

From Table 5.2.3-1 the minimum tensile strength is 68 ksi, so the ultimate tensile capacity of the screw is

$$\frac{1900}{(1.25)(3)} = 510\text{ lb}$$

The allowable tension is, then, the least of 77, 150, and 510 1b, or 77 1b.