



# Steel Tension Member Design by ASD/LRFD Steel Construction Manual

An Online Continuing Education Course for Engineers

**Course Number: C-2022**

**Credit: 2 Hours / 2 PDH / 2 CPD**

# Steel Tension Member Design by ASD/LRFD Steel Construction Manual 13<sup>th</sup> Edition

Tension members are found in trusses, towers, bracing members, hangers, tie rods and sag rods. Tension members can be structural steel sections, plates, built-up members, eyebars, pin-connected members, rods, bars, wire rope and steel cables. Tension members are one of the simplest to design. Tension members are now connected by bolts or welds. There are a few limit states for tension members. Section D of the specifications covers *Design of Members for Tension*.

- D1. Slenderness Limitations
- D2. Tensile Strength
- D3. Area Determination
- D4. Built-up Members
- D5. Pin-connected Members
- D6 Eyebars

We will look at the first three, since they apply to most tension members.

## D1. SLENDERNESS LIMITATIONS

There is no required slenderness limit but it is suggested the L/r should be less than 300. Rods and hangers in tension are exempt.

### Example 1

Let's say we have an angle, L4X4X1/2 that is under tension and 26 feet long, what is its L/r ratio?

1	Shape	Weight w lbs/ft	Area A in <sup>2</sup>	Depth d in	b <sub>f</sub> in	t <sub>w</sub> in	t <sub>f</sub> in	k <sub>des</sub> in	b <sub>f</sub> /2t <sub>f</sub>	h/t <sub>f</sub>	I <sub>x</sub> in <sup>4</sup>	Z <sub>x</sub> in <sup>3</sup>	S <sub>x</sub> in <sup>3</sup>	r <sub>x</sub> in	I <sub>y</sub> in <sup>4</sup>	Z <sub>y</sub> in <sup>3</sup>	S <sub>y</sub> in <sup>3</sup>	r <sub>y</sub> in	r <sub>z</sub> in	J in <sup>4</sup>
469	L4X4X3/4	18.5	5.44	4.00	0.00	0.00	0.00	1.13	0.00	0.00	7.62	5.02	2.79	1.18	7.62	5.01	2.79	1.18	0.774	1.0
470	L4X4X5/8	15.7	4.61	4.00	0.00	0.00	0.00	1.00	0.00	0.00	6.62	4.28	2.38	1.20	6.62	4.28	2.38	1.20	0.774	0.61
471	L4X4X1/2	12.8	3.75	4.00	0.00	0.00	0.00	0.875	0.00	0.00	5.52	3.50	1.96	1.21	5.52	3.50	1.96	1.21	0.776	0.32
472	L4X4X7/16	11.3	3.31	4.00	0.00	0.00	0.00	0.813	0.00	0.00	4.93	3.10	1.73	1.22	4.93	3.10	1.73	1.22	0.777	0.22
473	L4X4X3/8	9.80	2.86	4.00	0.00	0.00	0.00	0.750	0.00	0.00	4.32	2.69	1.50	1.23	4.32	2.68	1.50	1.23	0.779	0.14
474	L4X4X5/16	8.20	2.40	4.00	0.00	0.00	0.00	0.688	0.00	0.00	3.67	2.26	1.27	1.24	3.67	2.26	1.27	1.24	0.781	0.08
475	L4X4X1/4	6.60	1.94	4.00	0.00	0.00	0.00	0.625	0.00	0.00	3.00	1.82	1.02	1.25	3.00	1.82	1.02	1.25	0.782	0.04

$$L/r_z = (26 \text{ ft} \times 12 \text{ in/ft}) / 0.776 \text{ in} = 402 > 300 \text{ This would be no good.}$$

Be sure to watch your units so they cancel.

## D2. TENSILE STRENGTH

The *design tensile strength*,  $\phi_t P_n$ , and the *allowable tensile strength*,  $P_n/\Omega_t$ , of tension members, shall be the lower value obtained according to the *limit states of tensile yielding* in the gross section and *tensile rupture* in the net section.

(a) For tensile yielding in the gross section:

$$P_n = F_y A_g \quad (D2-1)$$
$$\phi_t = 0.90 \text{ (LRFD)} \quad \Omega_t = 1.67 \text{ (ASD)}$$

(b) For tensile rupture in the net section:

$$P_n = F_u A_e \quad (D2-2)$$
$$\phi_t = 0.75 \text{ (LRFD)} \quad \Omega_t = 2.00 \text{ (ASD)}$$

where

$A_e$  = effective net area, in.<sup>2</sup> (mm<sup>2</sup>)

$A_g$  = gross area of member, in.<sup>2</sup> (mm<sup>2</sup>)

$F_y$  = specified minimum yield stress of the type of steel being used, ksi (MPa)

$F_u$  = specified minimum tensile strength of the type of steel being used, ksi (MPa)

Steel tension member selection tables are in part 5 of the Steel Construction Manual. The tables list the available strength for different sections. The tensile rupture strength is based on  $A_e = 0.75A_g$ .

- Table 5-1. W-Shapes
- Table 5-2. Single Angles
- Table 5-3. WT-Shapes
- Table 5-4. Rectangular HSS
- Table 5-5. Square HSS
- Table 5-6. Round HSS
- Table 5-7. Steel Pipe
- Table 5-8. Double Angles

These tables can be easily produced in Excel. [Table 5-1](#)

### D3. AREA DETERMINATION

#### Gross Area

The gross area,  $A_g$ , of a member is the total cross-sectional area.

#### Net Area

The *net area*,  $A_n$ , of a member is the sum of the products of the thickness and the net width of each element computed as follows:

In computing net area for tension and shear, the width of a bolt hole shall be taken as  $1/16$  in. (2 mm) greater than the *nominal dimension* of the hole.

For a chain of holes extending across a part in any diagonal or zigzag line, the net width of the part shall be obtained by deducting from the gross width the sum of the diameters or slot dimensions as provided in Section J3.2, of all holes in the chain, and adding, for each *gage* space in the chain, the quantity  $s^2/4g$

where

$s$  = longitudinal center-to-center spacing (*pitch*) of any two consecutive holes, in. (mm)

$g$  = transverse center-to-center spacing (*gage*) between *fastener* gage lines, in. (mm)

#### Effective Net Area

The effective area of tension members shall be determined as follows:

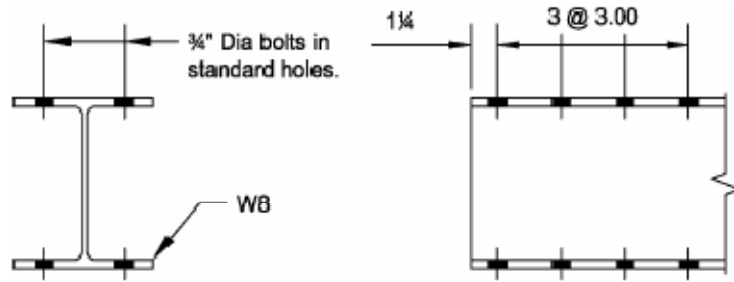
$$A_e = A_n U \quad (\text{D3-1})$$

where  $U$ , the shear lag factor, is determined as shown in Table D3.1.

**Note:** The *nominal dimension* of the hole for a standard hole is the bolt diameter plus  $1/16$  inch so the bolt hole shall be taken as this plus  $1/16$  inch or the bolt diameter plus  $1/8$  inch. That is  $(d_{\text{hole}} + 1/16)$  or  $(d_{\text{bolt}} + 1/8)$ .

#### Example 2

Select an 8 inch W-shape, ASTM A992, to carry a dead load of 40 kips and a live load of 100 kips in tension. The member is 26 feet long. There are four lines of  $3/4$  in diameter bolts in the flanges.



Since the material is ASTM A992 then  $F_y=50$  ksi and  $F_u=65$  ksi.

### LRFD

$$P_u = (1.2 \times 40 \text{ kips}) + (1.6 \times 100 \text{ kips})$$

$$P_u = 208 \text{ kips}$$

### ASD

$$P_a = 40 \text{ kips} + 100 \text{ kips}$$

$$P_a = 140 \text{ kips}$$

Try a W8 X 21

Shape	Weight w lbs/ft	Area A in <sup>2</sup>	Depth d in	b <sub>f</sub> in	t <sub>w</sub> in	t <sub>f</sub> in	k <sub>des</sub> in	b <sub>f</sub> /2t <sub>f</sub>	h/t <sub>f</sub>	I <sub>x</sub> in <sup>4</sup>	Z <sub>x</sub> in <sup>3</sup>	S <sub>x</sub> in <sup>3</sup>	r <sub>x</sub> in	I <sub>y</sub> in <sup>4</sup>	Z <sub>y</sub> in <sup>3</sup>	S <sub>y</sub> in <sup>3</sup>	r <sub>y</sub> in	r <sub>z</sub> in
W8X35	35.0	10.3	8.12	8.02	0.310	0.495	0.889	8.10	20.5	127	34.7	31.2	3.51	42.6	16.1	10.6	2.03	0.00
W8X31	31.0	9.12	8.00	8.00	0.285	0.435	0.829	9.19	22.3	110	30.4	27.5	3.47	37.1	14.1	9.27	2.02	0.00
W8X28	28.0	8.24	8.06	6.54	0.285	0.465	0.859	7.03	22.3	98.0	27.2	24.3	3.45	21.7	10.1	6.63	1.62	0.00
W8X24	24.0	7.08	7.93	6.50	0.245	0.400	0.794	8.12	25.9	82.7	23.1	20.9	3.42	18.3	8.57	5.63	1.61	0.00
W8X21	21.0	6.16	8.28	5.27	0.250	0.400	0.700	6.59	27.5	75.3	20.4	18.2	3.49	9.77	5.69	3.71	1.26	0.00
W8X18	18.0	5.26	8.14	5.25	0.230	0.330	0.630	7.95	29.9	61.9	17.0	15.2	3.43	7.97	4.66	3.04	1.23	0.00
W8X15	15.0	4.44	8.11	4.01	0.245	0.315	0.615	6.37	28.1	48.0	13.6	11.8	3.29	3.41	2.67	1.70	0.876	0.00
W8X13	13.0	3.84	7.99	4.00	0.230	0.255	0.555	7.84	29.9	39.6	11.4	9.91	3.21	2.73	2.15	1.37	0.843	0.00
W8X10	10.0	2.96	7.89	3.94	0.170	0.205	0.505	9.61	10.5	30.8	8.87	7.81	3.22	2.09	1.66	1.06	0.841	0.00

$$\bar{y} = 0.831 \text{ in (for WT4 X 10.5)}$$

### LRFD

$$\phi P_n = 0.90 F_y A_g = 0.90(50 \text{ ksi})(6.16 \text{ in}^2) = 277 \text{ kips}$$

### ASD

$$\frac{P_n}{\Omega} = \frac{F_y A_g}{1.67} = \frac{(50 \text{ ksi})(6.16 \text{ in}^2)}{1.67} = 184 \text{ kips}$$

