(18)

B. Sc. Engg. (CEE)/7th Semester

22 December, 2023
Morning (9:00 am -12:00 pm)

ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)
ORGANISATION OF ISLAMIC COOPERATION (OIC)
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

Semester Final Examination | **Winter Semester: 2022–2023**
Course Number: CEE 4713 | **Full Marks: 150**
Course Title: Design of Steel Structures | **Time: 3.0 Hours**

There are 6 (six) questions. Answer all questions. The figures in the right margin indicate full marks. COs and POs are also specified in the right margin of the questions. The symbols have their usual meaning.

1. A W 18 x 71 beam (A572 Gr. 50) has to transfer 75 kip-ft dead load and 140 kip-ft live load moment on to a W 21 x 201 (A 572 Gr. 50) column on its strong axis through an extended end plate type connection as shown in **Fig. 1**. Determine the suitable dimension as well as the thickness of the end plate and the bolt diameter. Use A572 Gr. 50 steel as end plate material and A325 bolts. Draw the complete diagram of the connection with appropriate dimensions. **(CO3) (PO3) (25)**

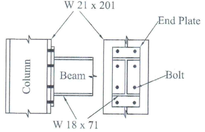


Fig. 1 for Question 1

2. (a) Explain the requirements that must be fulfilled in order to weld a beam with endplate for extended endplate connections. **(CO1) (PO1) (5)**

(b) The beam-column shown in **Fig. 2** is pinned at both ends and is subjected to the loads shown. Bending is about the string axis. Determine whether this member satisfies the appropriate AISC Specification interactions equation. Follow LRFD approach and consider moment amplification. The column is not braced except at the ends. Take C_b= 1.32 for flexure. **(CO2) (PO2) (20)**

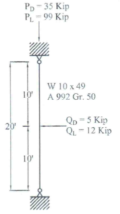


Fig. 2 for Question 2 (b)

3. (a) Explain the requirements that a knee connection must fulfill in order to be adequately designed. **(CO1) (PO1) (5)**

(b) Calculate the moment capacity of the plate PL $\frac{1}{2}$ x 7 $\frac{1}{2}$ attached to a gusset plate with four bolts as shown in **Fig. 3**. The material is A 36 (F_y = 36 ksi, F_u = 58 ksi). Bolts are 1 inch in diameter with standard holes. Use both LRFD and ASD Method. **(CO2) (PO2) (20)**

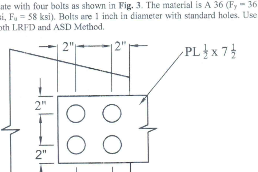


Fig. 3 for Question 3 (b)

4. (a) Explain the assumptions that are considered for using the alignment chart to calculate the effect length of compression members. (CO1) (PO1) (5)

(b) Determine the allowable compressive load carrying capacity of the column shown in **Fig. 4**. It consists of W 10 X 45 section having A992 (F_y = 50 ksi) steel. There are hinge support at top and bottom that allow rotation in any direction. Also the column has weak direction support (braced) at mid-height so that lateral deflection in prevented in x direction. Use LRFD approach. (CO2) (PO2) (20)

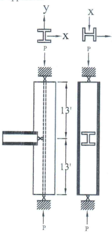


Fig. 4 for Question 4 (a)

5. Select the lightest W section for the beam shown in **Fig. 5** to carry a uniformly distributed service live load of 4.5 kip/ft. The simply supported span in 30 ft. The compression flange of the beam is fully supported against lateral movement. Use ASD method and select for A 992 steel. (CO3) (PO3) (25)

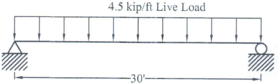


Fig. 5 for Question 5

6. Design an all bolted double-angle connection between a W 18 x 50 beam and a W 21 x 62 girder web shown in **Fig. 6** to support the following beam end reactions R_D = 40 kips, R_L = 50 kips. The beam top flange is coped 2-in deep by 4 in Long. L_{ev} =1 $^1/_4$ in., L_{eh} = 1 $^3/_4$ in., Use $^3/_4$ in. diameter A 325-N bolts in (CO3) (PO3) (25)

standard holes. Beams are A572 Grade 50 material. Draw the complete diagram of the connection with appropriate dimensions.

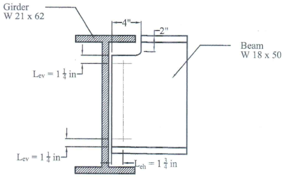


Fig. 6 for Question 6

LRFD Design

Block Shear Strength

Shear yielding - tension rupture $(0.6F_yA_{gv} < 0.6F_uA_{nv})$

$$\phi_t T_n = \phi_t\,(0.6F_yA_{gv} + F_uU_{bs}A_{nt}) = 0.75\,(0.6F_yA_{gv} + F_uU_{bs}A_{nt})$$

Shear fracture - tension rupture $(0.6F_uA_{nv} \geq 0.6F_yA_{gv})$

$$\phi_t T_n = \phi_t\,(0.6F_uA_{nv} + F_uU_{bs}A_{nt}) = 0.75(0.6F_uA_{nv} + F_uU_{bs}A_{nt})$$

where

A_{gv} : gross area acted upon by shear

A_{nt} : net area acted upon by tension

A_{nv} : net area acted upon by shear

F_u : specified (ASTM) minimum tensile strength

F_y : specified (ASTM) minimum yield stress

Note that the resistance factor ϕ_t is 0.75 for block shear.

AISC INTERACTION FORMULA

LRFD interaction equations

$$\frac{P_u}{\phi_c P_n} + \frac{8}{9}\left[\frac{M_{ux}}{\phi_b M_{nx}} + \frac{M_{uy}}{\phi_b M_{ny}}\right] \leq 1.0 \quad \text{For} \quad \frac{P_u}{\phi_c P_n} \geq 0.2$$

$$\frac{P_u}{2\phi_c P_n} + \left[\frac{M_{ux}}{\phi_b M_{nx}} + \frac{M_{uy}}{\phi_b M_{ny}}\right] \leq 1.0 \quad \text{For} \quad \frac{P_u}{\phi_c P_n} < 0.2$$

$$B = \frac{1}{1 - \frac{P_u}{P_e}}$$

ASD Design

Block Shear Strength

Shear yielding - tension rupture $(0.6F_yA_{gv} < 0.6F_uA_{nv})$

$$T_n/\Omega = (0.6F_yA_{gv} + F_uU_{bs}A_{nt})/\Omega = (0.6F_yA_{gv} + F_uU_{bs}A_{nt})/2.0$$

Shear fracture - tension rupture $(0.6F_yA_{gv} \geq 0.6F_uA_{nv})$

$$T_n/\Omega = (0.6F_uA_{nv} + F_uU_{bs}A_{nt})/\Omega = (0.6F_uA_{nv} + F_uU_{bs}A_{nt})/2.0$$

Where,

A_{gv} : gross area acted upon by shear

A_{nt} : net area acted upon by tension

A_{nv} : net area acted upon by shear

F_u : specified (ASTM) minimum tensile strength

F_y : specified (ASTM) minimum yield stress

Safety factor Ω = 2.00 for block shear which is essentially a fracture limit state

Element	λ	λ_p	λ_r
Flange	$\dfrac{b_f}{2t_f}$	$0.38\sqrt{\dfrac{E}{F_y}}$	$1.0\sqrt{\dfrac{E}{F_y}}$
Web	$\dfrac{h}{t_w}$	$3.76\sqrt{\dfrac{E}{F_y}}$	$5.70\sqrt{\dfrac{E}{F_y}}$

*For hot-rolled I shapes in flexure.

SUMMARY OF MOMENT STRENGTH

The procedure for computation of nominal moment strength for I and C-shaped sections bent about the x axis will now be summarized. All terms in the following equations have been previously defined, and AISC equation numbers will not be shown.

This summary is for compact and noncompact shapes (noncompact flanges) only (no slender shapes).

1. Determine whether the shape is compact.
2. If the shape is compact, check for lateral-torsional buckling as follows.
   If $L_b \leq L_p$, there is no LTB, and $M_n = M_p$
   If $L_p < L_b \leq L_r$, there is inelastic LTB, and

$$M_n = C_b\left[M_p - (M_p - 0.7F_yS_x)\left(\frac{L_b - L_p}{L_r - L_p}\right)\right] \leq M_p$$

   If $L_b > L_r$, there is elastic LTB, and

$$M_n = F_{cr}S_x \leq M_p$$

   where

$$F_{cr} = \frac{C_b\pi^2E}{(L_b/r_{ts})^2}\sqrt{1 + 0.078\frac{Jc}{S_xh_0}\left(\frac{L_b}{r_{ts}}\right)^2}$$

3. If the shape is noncompact because of the flange, the nominal strength will be the smaller of the strengths corresponding to flange local buckling and lateral-torsional buckling.
   a. Flange local buckling:
      If $\lambda \leq \lambda_p$, there is no FLB
      If $\lambda_p < \lambda \leq \lambda_r$, the flange is noncompact, and

$$M_n = M_p - (M_p - 0.7F_yS_x)\left(\frac{\lambda - \lambda_p}{\lambda_r - \lambda_p}\right)$$

   b. Lateral-torsional buckling:
      If $L_b \leq L_p$, there is no LTB
      If $L_p < L_b \leq L_r$, there is inelastic LTB, and

$$M_n = C_b\left[M_p - (M_p - 0.7F_yS_x)\left(\frac{L_b - L_p}{L_r - L_p}\right)\right] \leq M_p$$

      If $L_b > L_r$, there is elastic LTB, and

$$M_n = F_{cr}S_x \leq M_p$$

      where

$$F_{cr} = \frac{C_b\pi^2E}{(L_b/r_{ts})^2}\sqrt{1 + 0.078\frac{Jc}{S_xh_0}\left(\frac{L_b}{r_{ts}}\right)^2}$$

LATERAL BRACING REQUIREMENT

Unbraced length L_p to achieve just M_p: Inelastic LTB of compact sections (Case-2)

$$\frac{L_p}{r_y} = 1.76\sqrt{\frac{E}{F_y}} = \frac{300}{\sqrt{F_y,\ \text{ksi}}} \qquad (9.5.5)$$

Unbraced length L_r to achieve $M_r = 0.7F_yS_x$: LTB of compact sections (Case-3).

$$L_r = 1.95r_{ts}\frac{E}{0.7F_y}\sqrt{\frac{Jc}{S_xh_o}}\sqrt{1 + \sqrt{1 + 6.76\left(\frac{0.7F_y}{E}\frac{S_xh_o}{Jc}\right)^2}} \qquad (9.6.6)$$

where $r_{ts}^2 = \dfrac{\sqrt{I_yC_w}}{S_x}$

$c = 1$ for a doubly symmetric I-shape

$c = \dfrac{h_o}{2}\sqrt{\dfrac{I_y}{C_w}}$ for a channel

h_o = distance between the flange centroids, in.

Approximately

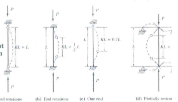
$$r_{ts} = \frac{b_f}{\sqrt{12\left(1 + \frac{1}{6}\frac{ht_w}{b_ft_f}\right)}}$$

Nominal strength $P_n = F_{cr}A_g$

1. $F_{cr} = \left[0.658^{\frac{F_y}{F_e}}\right]F_y$ For $\dfrac{KL}{r} \leq 4.71\sqrt{\dfrac{E}{F_y}}$ or $F_e \geq 0.44F_y$ **(6.7.7)**
2. $F_{cr} = 0.877F_e$ For $\dfrac{KL}{r} > 4.71\sqrt{\dfrac{E}{F_y}}$ or $F_e < 0.44F_y$ **(6.7.8)**

F_e is the elastic (Euler) buckling stress: $F_e = F_{cr} = \dfrac{\pi^2E}{\left(\dfrac{KL}{r}\right)^2}$

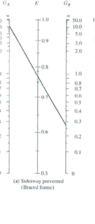
Effective Length For no joint translation



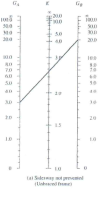
(a) End rotations unrestrained (b) End rotations fully restrained (c) One end restrained, other unrestrained (d) Partially restrained at each end

Stiffness modification factors for beams:

Condition	Sidesway (unbraced)	No sidesway (braced)
Far end of beam hinged	0.5	1.5
Far end of beam fixed	0.667	2.0



(a) Sidesway prevented (Braced frame)



(a) Sidesway not prevented (Unbraced frame)

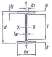


Table 1-1 (continued)
W-Shapes
Dimensions

Shape	Area, A	Depth, d		Web Thickness, t_w		$t_w/2$	Flange Width, b_f		Flange Thickness, t_f		Distance k k_{des}	k_{det}	k_1	T	Workable Gage
	in.²	in.		in.		in.	in.		in.		in.	in.	in.	in.	in.
W24x370[h]	109	28.0	28	1.52	1 1/2	3/4	13.7	13 5/8	2.72	2 3/4	3.22	3 5/8	1 9/16	20 3/4	5 1/2
x335[h]	98.3	27.5	27 1/2	1.38	1 3/8	11/16	13.5	13 1/2	2.48	2 1/2	2.98	3 3/8	1 1/2		
x306[h]	89.7	27.1	27 1/8	1.26	1 1/4	5/8	13.4	13 3/8	2.28	2 1/4	2.78	3 3/16	1 7/16		
x279[h]	81.9	26.7	26 3/4	1.16	1 3/16	5/8	13.3	13 1/4	2.09	2 1/16	2.59	3	1 7/16		
x250	73.5	26.3	26 3/8	1.04	1 1/16	9/16	13.2	13 1/8	1.89	1 7/8	2.39	2 13/16	1 3/8		
x229	67.2	26.0	26	0.960	15/16	1/2	13.1	13 1/8	1.73	1 3/4	2.23	2 5/8	1 5/16		
x207	60.7	25.7	25 3/4	0.870	7/8	7/16	13.0	13	1.57	1 9/16	2.07	2 1/2	1 1/4		
x192	56.5	25.5	25 1/2	0.810	13/16	7/16	13.0	13	1.46	1 7/16	1.96	2 3/8	1 1/4		
x176	51.7	25.2	25 1/4	0.750	3/4	3/8	12.9	12 7/8	1.34	1 5/16	1.84	2 1/4	1 3/16		
x162	47.8	25.0	25	0.705	11/16	3/8	13.0	13	1.22	1 1/4	1.72	2 1/8	1 3/16		
x146	43.0	24.7	24 3/4	0.650	5/8	5/16	12.9	12 7/8	1.09	1 1/16	1.59	2	1 1/8		
x131	38.6	24.5	24 1/2	0.605	5/8	5/16	12.9	12 7/8	0.960	15/16	1.46	1 7/8	1 1/8		
x117[c]	34.4	24.3	24 1/4	0.550	9/16	5/16	12.8	12 3/4	0.850	7/8	1.35	1 3/4	1 1/8		
x104[c]	30.7	24.1	24	0.500	1/2	1/4	12.8	12 3/4	0.750	3/4	1.25	1 5/8	1 1/16		
W24x103[c]	30.3	24.5	24 1/2	0.550	9/16	5/16	9.00	9	0.980	1	1.48	1 7/8	1 1/8	20 3/4	5 1/2
x94[c]	27.7	24.3	24 1/4	0.515	1/2	1/4	9.07	9 1/8	0.875	7/8	1.38	1 3/4	1 1/16		
x84[c]	24.7	24.1	24 1/8	0.470	1/2	1/4	9.02	9	0.770	3/4	1.27	1 11/16	1 1/16		
x76[c]	22.4	23.9	23 7/8	0.440	7/16	1/4	8.99	9	0.680	11/16	1.18	1 9/16	1 1/16		
x68[c]	20.1	23.7	23 3/4	0.415	7/16	1/4	8.97	9	0.585	9/16	1.09	1 1/2	1 1/16		
W24x62[c]	18.2	23.7	23 3/4	0.430	7/16	1/4	7.04	7	0.590	9/16	1.09	1 1/2	1 1/16	20 3/4	3 1/2[g]
x55[c,v]	16.2	23.6	23 5/8	0.395	3/8	3/16	7.01	7	0.505	1/2	1.01	1 7/16	1	20 3/4	3 1/2[g]
W21x201	59.3	23.0	23	0.910	15/16	1/2	12.6	12 5/8	1.63	1 5/8	2.13	2 1/2	1 5/16	18	5 1/2
x182	53.6	22.7	22 3/4	0.830	13/16	7/16	12.5	12 1/2	1.48	1 1/2	1.98	2 3/8	1 1/4		
x166	48.8	22.5	22 1/2	0.750	3/4	3/8	12.4	12 3/8	1.36	1 3/8	1.86	2 1/4	1 3/16		
x147	43.2	22.1	22	0.720	3/4	3/8	12.5	12 1/2	1.15	1 1/8	1.65	2	1 3/16		
x132	38.8	21.8	21 7/8	0.650	5/8	5/16	12.4	12 1/2	1.04	1 1/16	1.54	1 15/16	1 1/8		
x122	35.9	21.7	21 5/8	0.600	5/8	5/16	12.4	12 3/8	0.960	15/16	1.46	1 13/16	1 1/8		
x111	32.6	21.5	21 1/2	0.550	9/16	5/16	12.3	12 3/8	0.875	7/8	1.38	1 3/4	1 1/8		
x101[c]	29.8	21.4	21 3/8	0.500	1/2	1/4	12.3	12 1/4	0.800	13/16	1.30	1 11/16	1 1/16		

[c] Shape is slender for compression with $F_y = 50$ ksi.
[g] The actual size, combination and orientation of fastener components should be compared with the geometry of the cross section to ensure compatibility.
[h] Flange thickness greater than 2 in. Special requirements may apply per AISC *Specification* Section A3.1c.
[v] Shape does not meet the h/t_w limit for shear in AISC *Specification* Section G2.1(a) with $F_y = 50$ ksi.

Table 1-1 (continued)
W-Shapes
Properties

W24-W21

Nom-inal Wt.	Compact Section Criteria $b_f/2t_f$	h/t_w	Axis X-X I	S	r	Z	Axis Y-Y I	S	r	Z	r_{ts}	h_o	Torsional Properties J	C_w
lb/ft			in.⁴	in.³	in.	in.³	in.⁴	in.³	in.	in.³	in.	in.	in.⁴	in.⁶
370	2.51	14.2	13400	957	11.1	1130	1160	170	3.27	267	3.92	25.3	201	186000
335	2.73	15.6	11900	864	11.0	1020	1030	152	3.23	238	3.86	25.0	152	161000
306	2.94	17.1	10700	789	10.9	922	919	137	3.20	214	3.81	24.8	117	142000
279	3.18	18.6	9600	718	10.8	835	823	124	3.17	193	3.76	24.6	90.5	125000
250	3.49	20.7	8490	644	10.7	744	724	110	3.14	171	3.71	24.4	66.6	108000
229	3.79	22.5	7650	588	10.7	675	651	99.4	3.11	154	3.67	24.3	51.3	96100
207	4.14	24.8	6820	531	10.6	606	578	88.8	3.08	137	3.62	24.1	38.3	84100
192	4.43	26.6	6260	491	10.5	559	530	81.8	3.07	126	3.60	24.0	30.8	76300
176	4.81	28.7	5680	450	10.5	511	479	74.3	3.04	115	3.57	23.9	23.9	68400
162	5.31	30.6	5170	414	10.4	468	443	68.4	3.05	105	3.57	23.8	18.5	62600
146	5.92	33.2	4580	371	10.3	418	391	60.5	3.01	93.2	3.53	23.6	13.4	54600
131	6.70	35.6	4020	329	10.2	370	340	53.0	2.97	81.5	3.49	23.5	9.50	47100
117	7.53	39.2	3540	291	10.1	327	297	46.5	2.94	71.4	3.46	23.5	6.72	40800
104	8.50	43.1	3100	258	10.1	289	259	40.7	2.91	62.4	3.42	23.4	4.72	35200
103	4.59	39.2	3000	245	10.0	280	119	26.5	1.99	41.5	2.40	23.5	7.07	16600
94	5.18	41.9	2700	222	9.87	254	109	24.0	1.98	37.5	2.40	23.4	5.26	15000
84	5.86	45.9	2370	196	9.79	224	94.4	20.9	1.95	32.6	2.37	23.3	3.70	12800
76	6.61	49.0	2100	176	9.69	200	82.5	18.4	1.92	28.6	2.33	23.2	2.68	11100
68	7.66	52.0	1830	154	9.55	177	70.4	15.7	1.87	24.5	2.30	23.1	1.87	9430
62	5.97	50.1	1550	131	9.23	153	34.5	9.80	1.38	15.7	1.75	23.1	1.71	4620
55	6.94	54.6	1350	114	9.11	134	29.1	8.30	1.34	13.3	1.72	23.1	1.18	3870
201	3.86	20.6	5310	461	9.47	530	542	86.1	3.02	133	3.55	21.4	40.9	62000
182	4.22	22.6	4730	417	9.40	476	483	77.2	3.00	119	3.51	21.2	30.7	54400
166	4.57	25.0	4280	380	9.36	432	435	70.0	2.99	108	3.48	21.1	23.6	48500
147	5.44	26.1	3630	329	9.17	373	376	60.1	2.95	92.6	3.46	21.0	15.4	41100
132	6.01	28.9	3220	295	9.12	333	333	53.5	2.93	82.3	3.43	20.8	11.3	36000
122	6.45	31.3	2960	273	9.09	307	305	49.2	2.92	75.6	3.40	20.7	8.98	32700
111	7.05	34.1	2670	249	9.05	279	274	44.5	2.90	68.2	3.37	20.6	6.83	29200
101	7.68	37.5	2420	227	9.02	253	248	40.3	2.89	61.7	3.35	20.6	5.21	26200

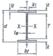


Table 1-1 (continued)
W-Shapes
Dimensions

Shape	Area, A	Depth, d		Web Thickness, t_w		Web $\frac{t_w}{2}$	Flange Width, b_f		Flange Thickness, t_f		Distance k k_{des}	Distance k k_{det}	Distance k_1	Distance T	Distance Workable Gage
	in.^{2}	in.		in.		in.	in.		in.		in.	in.	in.	in.	in.
W21×93	27.3	21.6	21 5/8	0.580	9/16	5/16	8.42	8 3/8	0.930	15/16	1.43	1 5/8	15/16	18 3/8	5 1/2
×83[c]	24.4	21.4	21 3/8	0.515	1/2	1/4	8.36	8 3/8	0.835	13/16	1.34	1 1/2	7/8		
×73[c]	21.5	21.2	21 1/4	0.455	7/16	1/4	8.30	8 1/4	0.740	3/4	1.24	1 7/16	7/8		
×68[c]	20.0	21.1	21 1/8	0.430	7/16	1/4	8.27	8 1/4	0.685	11/16	1.19	1 3/8	7/8		
×62[c]	18.3	21.0	21	0.400	3/8	3/16	8.24	8 1/4	0.615	5/8	1.12	1 5/16	13/16		
×55[c]	16.2	20.8	20 3/4	0.375	3/8	3/16	8.22	8 1/4	0.522	1/2	1.02	1 3/16	13/16		
×48[c,f]	14.1	20.6	20 5/8	0.350	3/8	3/16	8.14	8 1/8	0.430	7/16	0.930	1 1/8	13/16		
W21×57[c]	16.7	21.1	21	0.405	3/8	3/16	6.56	6 1/2	0.650	5/8	1.15	1 5/16	13/16	18 3/8	3 1/2
×50[c]	14.7	20.8	20 7/8	0.380	3/8	3/16	6.53	6 1/2	0.535	9/16	1.04	1 1/4	13/16		
×44[c]	13.0	20.7	20 5/8	0.350	3/8	3/16	6.50	6 1/2	0.450	7/16	0.950	1 1/8	13/16		
W18×311[h]	91.6	22.3	22 3/8	1.52	1 1/2	3/4	12.0	12	2.74	2 3/4	3.24	3 7/16	1 3/8	15 1/2	5 1/2
×283[h]	83.3	21.9	21 7/8	1.40	1 3/8	11/16	11.9	11 7/8	2.50	2 1/2	3.00	3 3/16	1 5/16		
×258[h]	76.0	21.5	21 1/2	1.28	1 1/4	5/8	11.8	11 3/4	2.30	2 5/16	2.70	3	1 1/4		
×234[h]	68.6	21.1	21	1.16	1 3/16	5/8	11.7	11 5/8	2.11	2 1/8	2.51	2 3/4	1 3/16		
×211	62.3	20.7	20 5/8	1.06	1 1/16	9/16	11.6	11 1/2	1.91	1 15/16	2.31	2 9/16	1 3/16		
×192	56.2	20.4	20 3/8	0.960	15/16	1/2	11.5	11 1/2	1.75	1 3/4	2.15	2 7/16	1 1/8		
×175	51.4	20.0	20	0.890	7/8	7/16	11.4	11 3/8	1.59	1 9/16	1.99	2 7/16	1 1/4	15 1/8	
×158	46.3	19.7	19 3/4	0.810	13/16	7/16	11.3	11 1/4	1.44	1 7/16	1.84	2 3/8	1 1/4		
×143	42.0	19.5	19 1/2	0.730	3/4	3/8	11.2	11 1/4	1.32	1 5/16	1.72	2 3/16	1 3/16		
×130	38.3	19.3	19 1/4	0.670	11/16	3/8	11.2	11 1/8	1.20	1 3/16	1.60	2 1/16	1 3/16		
×119	35.1	19.0	19	0.655	5/8	5/16	11.3	11 1/4	1.06	1 1/16	1.46	1 15/16	1 3/16		
×106	31.1	18.7	18 3/4	0.590	9/16	5/16	11.2	11 1/4	0.940	15/16	1.34	1 13/16	1 1/8		
×97	28.5	18.6	18 5/8	0.535	9/16	5/16	11.1	11 1/8	0.870	7/8	1.27	1 3/4	1 1/8		
×86	25.3	18.4	18 3/8	0.480	1/2	1/4	11.1	11 1/8	0.770	3/4	1.17	1 5/8	1 1/16		
×76[c]	22.3	18.2	18 1/4	0.425	7/16	1/4	11.0	11	0.680	11/16	1.08	1 9/16	1 1/16		
W18×71	20.9	18.5	18 1/2	0.495	1/2	1/4	7.64	7 5/8	0.810	13/16	1.21	1 1/2	7/8	15 1/2	3 1/2[g]
×65	19.1	18.4	18 3/8	0.450	7/16	1/4	7.59	7 5/8	0.750	3/4	1.15	1 7/16	7/8		
×60[c]	17.6	18.2	18 1/4	0.415	7/16	1/4	7.56	7 1/2	0.695	11/16	1.10	1 3/8	13/16		
×55[c]	16.2	18.1	18 1/8	0.390	3/8	3/16	7.53	7 1/2	0.630	5/8	1.03	1 5/16	13/16		
×50[c]	14.7	18.0	18	0.355	3/8	3/16	7.50	7 1/2	0.570	9/16	0.972	1 1/4	13/16		
W18×46[c]	13.5	18.1	18	0.360	3/8	3/16	6.06	6	0.605	5/8	1.01	1 1/4	13/16	15 1/2	3 1/2[g]
×40[c]	11.8	17.9	17 7/8	0.315	5/16	3/16	6.02	6	0.525	1/2	0.927	1 3/16	13/16		
×35[c]	10.3	17.7	17 3/4	0.300	5/16	3/16	6.00	6	0.425	7/16	0.827	1 1/8	3/4		

[c] Shape is slender for compression with $F_y = 50$ ksi.
[f] Shape exceeds compact limit for flexure with $F_y = 50$ ksi.
[g] The actual size, combination and orientation of fastener components should be compared with the geometry of the cross section to ensure compatibility.
[h] Flange thickness greater than 2 in. Special requirements may apply per AISC *Specification* Section A3.1c.

Table 1-1 (continued)
W-Shapes
Properties

W21-W18

Nom-inal Wt.	Compact Section Criteria $\frac{b_f}{2t_f}$	Compact Section Criteria $\frac{h}{t_w}$	Axis X-X I	Axis X-X S	Axis X-X r	Axis X-X Z	Axis Y-Y I	Axis Y-Y S	Axis Y-Y r	Axis Y-Y Z	r_{ts}	h_o	Torsional Properties J	Torsional Properties C_w
lb/ft			in.^{4}	in.^{3}	in.	in.^{3}	in.^{4}	in.^{3}	in.	in.^{3}	in.	in.	in.^{4}	in.^{6}
93	4.53	32.3	2070	192	8.70	221	92.9	22.1	1.84	34.7	2.24	20.7	6.03	9940
83	5.00	36.4	1830	171	8.67	196	81.4	19.5	1.83	30.5	2.21	20.6	4.34	8630
73	5.60	41.2	1600	151	8.64	172	70.6	17.0	1.81	26.6	2.19	20.5	3.02	7410
68	6.04	43.6	1480	140	8.60	160	64.7	15.7	1.80	24.4	2.17	20.4	2.45	6760
62	6.70	46.9	1330	127	8.54	144	57.5	14.0	1.77	21.7	2.15	20.4	1.83	5960
55	7.87	50.0	1140	110	8.40	126	48.4	11.8	1.73	18.4	2.11	20.3	1.24	4980
48	9.47	53.6	959	93.0	8.24	107	38.7	9.52	1.66	14.9	2.05	20.2	0.803	3950
57	5.04	46.3	1170	111	8.36	129	30.6	9.35	1.35	14.8	1.68	20.5	1.77	3190
50	6.10	49.4	984	94.5	8.18	110	24.9	7.64	1.30	12.2	1.64	20.3	1.14	2570
44	7.22	53.6	843	81.6	8.06	95.4	20.7	6.37	1.26	10.2	1.60	20.3	0.770	2110
311	2.19	10.4	6970	624	8.72	754	795	132	2.95	207	3.53	19.6	176	76200
283	2.38	11.3	6170	565	8.61	676	704	118	2.91	185	3.47	19.4	134	65900
258	2.56	12.5	5510	514	8.53	611	628	107	2.88	166	3.42	19.2	103	57600
234	2.76	13.8	4900	466	8.44	549	558	95.8	2.85	149	3.37	19.0	78.7	50100
211	3.02	15.1	4330	419	8.35	490	493	85.3	2.82	132	3.32	18.8	58.6	43400
192	3.27	16.7	3870	380	8.28	442	440	76.8	2.79	119	3.28	18.7	44.7	38000
175	3.58	18.0	3450	344	8.20	398	391	68.8	2.76	106	3.24	18.4	33.8	33300
158	3.92	19.8	3060	310	8.12	356	347	61.4	2.74	94.8	3.20	18.3	25.2	29000
143	4.25	22.0	2750	282	8.09	322	311	55.5	2.72	85.4	3.17	18.2	19.2	25700
130	4.65	23.9	2460	256	8.03	290	278	49.9	2.70	76.7	3.13	18.1	14.5	22700
119	5.31	24.5	2190	231	7.90	262	253	44.9	2.69	69.1	3.13	17.9	10.6	20300
106	5.96	27.2	1910	204	7.84	230	220	39.4	2.66	60.5	3.10	17.8	7.48	17400
97	6.41	30.0	1750	188	7.82	211	201	36.1	2.65	55.3	3.08	17.7	5.86	15800
86	7.20	33.4	1530	166	7.77	186	175	31.6	2.63	48.4	3.05	17.6	4.10	13600
76	8.11	37.8	1330	146	7.73	163	152	27.6	2.61	42.2	3.02	17.5	2.83	11700
71	4.71	32.4	1170	127	7.50	146	60.3	15.8	1.70	24.7	2.05	17.7	3.49	4700
65	5.06	35.7	1070	117	7.49	133	54.8	14.4	1.69	22.5	2.03	17.7	2.73	4240
60	5.44	38.7	984	108	7.47	123	50.1	13.3	1.68	20.6	2.02	17.5	2.17	3850
55	5.98	41.1	890	98.3	7.41	112	44.9	11.9	1.67	18.5	2.00	17.5	1.66	3430
50	6.57	45.2	800	88.9	7.38	101	40.1	10.7	1.65	16.6	1.98	17.4	1.24	3040
46	5.01	44.6	712	78.8	7.25	90.7	22.5	7.43	1.29	11.7	1.58	17.5	1.22	1720
40	5.73	50.9	612	68.4	7.21	78.4	19.1	6.35	1.27	10.0	1.56	17.4	0.810	1440
35	7.06	53.5	510	57.6	7.04	66.5	15.3	5.12	1.22	8.06	1.51	17.3	0.506	1140

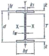


Table 1-1 (continued)
W-Shapes
Dimensions

Shape	Area, A	Depth, d		Web Thickness, t_w		Web $\frac{t_w}{2}$	Flange Width, b_f		Flange Thickness, t_f		Distance k k_{des}	Distance k k_{det}	Distance k_1	Distance T	Workable Gage
	in.^{2}	in.		in.		in.	in.		in.		in.	in.	in.	in.	in.
W12×58	17.0	12.2	12 1/4	0.360	3/8	3/16	10.0	10	0.640	5/8	1.24	1 1/2	15/16	9 1/4	5 1/2
×53	15.6	12.1	12	0.345	3/8	3/16	10.0	10	0.575	9/16	1.18	1 3/8	15/16	9 1/4	5 1/2
W12×50	14.6	12.2	12 1/4	0.370	3/8	3/16	8.08	8 1/8	0.640	5/8	1.14	1 1/2	15/16	9 1/4	5 1/2
×45	13.1	12.1	12	0.335	5/16	3/16	8.05	8	0.575	9/16	1.08	1 3/8	15/16	↓	↓
×40	11.7	11.9	12	0.295	5/16	3/16	8.01	8	0.515	1/2	1.02	1 3/8	7/8	↓	↓
W12×35[c]	10.3	12.5	12 1/2	0.300	5/16	3/16	6.56	6 1/2	0.520	1/2	0.820	1 3/16	3/4	10 1/8	3 1/2
×30[c]	8.79	12.3	12 3/8	0.260	1/4	1/8	6.52	6 1/2	0.440	7/16	0.740	1 1/8	3/4	↓	↓
×26[c]	7.65	12.2	12 1/4	0.230	1/4	1/8	6.49	6 1/2	0.380	3/8	0.680	1 1/16	3/4	↓	↓
W12×22[c]	6.48	12.3	12 1/4	0.260	1/4	1/8	4.03	4	0.425	7/16	0.725	15/16	5/8	10 3/8	2 1/4[g]
×19[c]	5.57	12.2	12 1/8	0.235	1/4	1/8	4.01	4	0.350	3/8	0.650	7/8	9/16	↓	↓
×16[c]	4.71	12.0	12	0.220	1/4	1/8	3.99	4	0.265	1/4	0.565	13/16	9/16	↓	↓
×14[c,v]	4.16	11.9	11 7/8	0.200	3/16	1/8	3.97	4	0.225	1/4	0.525	3/4	9/16	↓	↓
W10×112	32.9	11.4	11 3/8	0.755	3/4	3/8	10.4	10 3/8	1.25	1 1/4	1.75	1 15/16	1	7 1/2	5 1/2
×100	29.3	11.1	11 1/8	0.680	11/16	3/8	10.3	10 3/8	1.12	1 1/8	1.62	1 13/16	1	↓	↓
×88	26.0	10.8	10 7/8	0.605	5/8	5/16	10.3	10 1/4	0.990	1	1.49	1 11/16	15/16	↓	↓
×77	22.7	10.6	10 5/8	0.530	1/2	1/4	10.2	10 1/4	0.870	7/8	1.37	1 9/16	7/8	↓	↓
×68	19.9	10.4	10 3/8	0.470	1/2	1/4	10.1	10 1/8	0.770	3/4	1.27	1 7/16	7/8	↓	↓
×60	17.7	10.2	10 1/4	0.420	7/16	1/4	10.1	10 1/8	0.680	11/16	1.18	1 3/8	13/16	↓	↓
×54	15.8	10.1	10 1/8	0.370	3/8	3/16	10.0	10	0.615	5/8	1.12	1 5/16	13/16	↓	↓
×49	14.4	10.0	10	0.340	5/16	3/16	10.0	10	0.560	9/16	1.06	1 1/4	13/16	↓	↓
W10×45	13.3	10.1	10 1/8	0.350	3/8	3/16	8.02	8	0.620	5/8	1.12	1 5/16	13/16	7 1/2	5 1/2
×39	11.5	9.92	9 7/8	0.315	5/16	3/16	7.99	8	0.530	1/2	1.03	1 3/16	13/16	↓	↓
×33	9.71	9.73	9 3/4	0.290	5/16	3/16	7.96	8	0.435	7/16	0.935	1 1/8	3/4	↓	↓
W10×30	8.84	10.5	10 1/2	0.300	5/16	3/16	5.81	5 3/4	0.510	1/2	0.810	1 1/8	11/16	8 1/4	2 3/4[g]
×26	7.61	10.3	10 3/8	0.260	1/4	1/8	5.77	5 3/4	0.440	7/16	0.740	1 1/16	11/16	↓	↓
×22[c]	6.49	10.2	10 1/8	0.240	1/4	1/8	5.75	5 3/4	0.360	3/8	0.660	15/16	5/8	↓	↓
W10×19	5.62	10.2	10 1/4	0.250	1/4	1/8	4.02	4	0.395	3/8	0.695	15/16	5/8	8 3/8	2 1/4[g]
×17[c]	4.99	10.1	10 1/8	0.240	1/4	1/8	4.01	4	0.330	5/16	0.630	7/8	9/16	↓	↓
×15[c]	4.41	9.99	10	0.230	1/4	1/8	4.00	4	0.270	1/4	0.570	13/16	9/16	↓	↓
×12[c,f]	3.54	9.87	9 7/8	0.190	3/16	1/8	3.96	4	0.210	3/16	0.510	3/4	9/16	↓	↓

[c] Shape is slender for compression with $F_y = 50$ ksi.
[f] Shape exceeds compact limit for flexure with $F_y = 50$ ksi.
[g] The actual size, combination and orientation of fastener components should be compared with the geometry of the cross section to ensure compatibility.
[v] Shape does not meet the h/t_w limit for shear in AISC *Specification* Section G2.1(a) with $F_y = 50$ ksi.

Table 1-1 (continued)
W-Shapes
Properties

W12-W10

Nom-inal Wt.	Compact Section Criteria $\frac{b_f}{2t_f}$	Compact Section Criteria $\frac{h}{t_w}$	Axis X-X I	Axis X-X S	Axis X-X r	Axis X-X Z	Axis Y-Y I	Axis Y-Y S	Axis Y-Y r	Axis Y-Y Z	r_{ts}	h_o	Torsional Properties J	Torsional Properties C_w
lb/ft			in.^{4}	in.^{3}	in.	in.^{3}	in.^{4}	in.^{3}	in.	in.^{3}	in.	in.	in.^{4}	in.^{6}
58	7.82	27.0	475	78.0	5.28	86.4	107	21.4	2.51	32.5	2.81	11.6	2.10	3570
53	8.69	28.1	425	70.6	5.23	77.9	95.8	19.2	2.48	29.1	2.79	11.5	1.58	3160
50	6.31	26.8	391	64.2	5.18	71.9	56.3	13.9	1.96	21.3	2.25	11.6	1.71	1880
45	7.00	29.6	348	57.7	5.15	64.2	50.0	12.4	1.95	19.0	2.23	11.5	1.26	1650
40	7.77	33.6	307	51.5	5.13	57.0	44.1	11.0	1.94	16.8	2.21	11.4	0.906	1440
35	6.31	36.2	285	45.6	5.25	51.2	24.5	7.47	1.54	11.5	1.79	12.0	0.741	879
30	7.41	41.8	238	38.6	5.21	43.1	20.3	6.24	1.52	9.56	1.77	11.9	0.457	720
26	8.54	47.2	204	33.4	5.17	37.2	17.3	5.34	1.51	8.17	1.75	11.8	0.300	607
22	4.74	41.8	156	25.4	4.91	29.3	4.66	2.31	0.848	3.66	1.04	11.9	0.293	164
19	5.72	46.2	130	21.3	4.82	24.7	3.76	1.88	0.822	2.98	1.02	11.9	0.180	131
16	7.53	49.4	103	17.1	4.67	20.1	2.82	1.41	0.773	2.26	0.983	11.7	0.103	96.9
14	8.82	54.3	88.6	14.9	4.62	17.4	2.36	1.19	0.753	1.90	0.961	11.7	0.0704	80.4
112	4.17	10.4	716	126	4.66	147	236	45.3	2.68	69.2	3.08	10.2	15.1	6020
100	4.62	11.6	623	112	4.60	130	207	40.0	2.65	61.0	3.04	10.0	10.9	5150
88	5.18	13.0	534	98.5	4.54	113	179	34.8	2.63	53.1	2.99	9.81	7.53	4330
77	5.86	14.8	455	85.9	4.49	97.6	154	30.1	2.60	45.9	2.95	9.73	5.11	3630
68	6.58	16.7	394	75.7	4.44	85.3	134	26.4	2.59	40.1	2.92	9.63	3.56	3100
60	7.41	18.7	341	66.7	4.39	74.6	116	23.0	2.57	35.0	2.88	9.52	2.48	2640
54	8.15	21.2	303	60.0	4.37	66.6	103	20.6	2.56	31.3	2.85	9.49	1.82	2320
49	8.93	23.1	272	54.6	4.35	60.4	93.4	18.7	2.54	28.3	2.84	9.44	1.39	2070
45	6.47	22.5	248	49.1	4.32	54.9	53.4	13.3	2.01	20.3	2.27	9.48	1.51	1200
39	7.53	25.0	209	42.1	4.27	46.8	45.0	11.3	1.98	17.2	2.24	9.39	0.976	992
33	9.15	27.1	171	35.0	4.19	38.8	36.6	9.20	1.94	14.0	2.20	9.30	0.583	791
30	5.70	29.5	170	32.4	4.38	36.6	16.7	5.75	1.37	8.84	1.60	10.0	0.622	414
26	6.56	34.0	144	27.9	4.35	31.3	14.1	4.89	1.36	7.50	1.58	9.86	0.402	345
22	7.99	36.9	118	23.2	4.27	26.0	11.4	3.97	1.33	6.10	1.55	9.84	0.239	275
19	5.09	35.4	96.3	18.8	4.14	21.6	4.29	2.14	0.874	3.35	1.06	9.81	0.233	104
17	6.08	36.9	81.9	16.2	4.05	18.7	3.56	1.78	0.845	2.80	1.04	9.77	0.156	85.1
15	7.41	38.5	68.9	13.8	3.95	16.0	2.89	1.45	0.810	2.30	1.01	9.72	0.104	68.3
12	9.43	46.6	53.8	10.9	3.90	12.6	2.18	1.10	0.785	1.74	0.983	9.66	0.0547	50.9

F_y = 50 ksi

Table 3–2 (continued)
W Shapes
Selection by Z_x

Z_x

Shape	Z_x	M_{px}/Ω_b	$\phi_b M_{px}$	M_{rx}/Ω_b	$\phi_b M_{rx}$	BF		L_p	L_r	I_x	V_{nx}/Ω_v	$\phi_v V_{nx}$
		kip-ft	kip-ft	kip-ft	kip-ft	kips	kips				kips	kips
	in.[3]	ASD	LRFD	ASD	LRFD	ASD	LRFD	ft	ft	in.[4]	ASD	LRFD
W30×116	**378**	**943**	**1420**	**575**	**864**	**24.7**	**37.2**	**7.74**	**22.6**	**4930**	**339**	**509**
W21×147	373	931	1400	575	864	13.8	20.7	10.4	36.3	3630	318	476
W24×131	370	923	1390	575	864	16.3	24.5	10.5	31.9	4020	296	444
W18×158	356	888	1340	541	814	10.5	15.7	9.68	42.8	3060	319	479
W14×193	355	886	1330	541	814	5.27	7.92	14.3	79.7	2400	276	413
W12×210	348	868	1310	510	767	4.24	6.38	11.6	96.0	2140	347	521
W30×108	**346**	**863**	**1300**	**522**	**785**	**23.7**	**35.6**	**7.59**	**22.0**	**4470**	**325**	**488**
W27×114	343	856	1290	522	785	21.7	32.6	7.70	23.1	4080	311	467
W21×132	333	831	1250	515	774	13.3	20.0	10.3	34.1	3220	284	426
W24×117	327	816	1230	508	764	15.3	23.1	10.4	30.4	3540	267	400
W18×143	322	803	1210	493	740	10.4	15.6	9.61	39.6	2750	285	427
W14×176	320	798	1200	491	738	5.22	7.84	14.2	73.2	2140	253	379
W30×99	**312**	**778**	**1170**	**470**	**706**	**22.2**	**33.3**	**7.42**	**21.4**	**3990**	**308**	**463**
W12×190	311	776	1170	459	690	4.18	6.28	11.5	87.3	1890	305	457
W21×122	307	766	1150	477	717	12.9	19.4	10.3	32.7	2960	260	390
W27×102	305	761	1140	466	701	20.2	30.3	7.59	22.2	3620	279	419
W18×130	290	724	1090	447	672	10.2	15.3	9.54	36.7	2460	258	387
W24×104	289	721	1080	451	677	14.3	21.5	10.3	29.2	3100	241	361
W14×159	287	716	1080	444	667	5.18	7.79	14.1	66.7	1900	223	335
W30×90[v]	**283**	**706**	**1060**	**428**	**643**	**20.5**	**30.9**	**7.38**	**20.9**	**3610**	**249**	**375**
W24×103	280	699	1050	428	643	18.2	27.4	7.03	21.9	3000	270	405
W21×111	279	696	1050	435	654	12.4	18.7	10.2	31.3	2670	237	355
W27×94	278	694	1040	424	638	19.1	28.8	7.49	21.6	3270	264	396
W12×170	275	686	1030	410	617	4.11	6.18	11.4	78.5	1650	269	404
W18×119	262	654	983	403	606	10.1	15.2	9.50	34.3	2190	249	373
W14×145	260	649	975	405	609	5.11	7.68	14.1	61.7	1710	201	302
W24×94	254	634	953	388	583	17.3	26.0	6.99	21.2	2700	250	376
W21×101	253	631	949	396	596	11.8	17.7	10.2	30.1	2420	214	320
W27×84	**244**	**609**	**915**	**372**	**559**	**17.6**	**26.4**	**7.31**	**20.8**	**2850**	**246**	**369**
W12×152	243	606	911	365	549	4.07	6.11	11.3	70.6	1430	239	358
W14×132	234	584	878	365	549	5.13	7.70	13.3	56.0	1530	189	284
W18×106	230	574	863	356	536	9.70	14.6	9.40	31.8	1910	221	332

ASD	LRFD
$\Omega_b = 1.67$ $\Omega_v = 1.50$	$\phi_b = 0.90$ $\phi_v = 1.00$

[v] Shape does not meet the h/t_w limit for shear in Specification Section G2.1a with F_y = 50 ksi, $\Omega_v = 1.67$, $\phi_v = 0.90$.

Z_X

Table 3-2 (continued)
W Shapes
Selection by Z_x

$F_y = 50$ ksi

Shape	Z_x	M_{px}/Ω_b	$\phi_b M_{px}$	M_{rx}/Ω_b	$\phi_b M_{rx}$	BF	BF	L_p	L_r	I_x	V_{nx}/Ω_v	$\phi_v V_{nx}$
		kip-ft	kip-ft	kip-ft	kip-ft	kips	kips				kips	kips
	in.³	ASD	LRFD	ASD	LRFD	ASD	LRFD	ft	ft	in.⁴	ASD	LRFD
W24×84	**224**	**559**	**840**	**342**	**515**	**16.2**	**24.3**	**6.89**	**20.3**	**2370**	**227**	**340**
W21×93	221	551	829	335	504	14.6	21.9	6.50	21.3	2070	251	376
W12×136	214	534	803	325	488	4.01	6.03	11.2	63.3	1240	212	318
W14×120	212	529	795	332	499	5.09	7.64	13.2	52.0	1380	171	256
W18×97	211	526	791	328	494	9.45	14.2	9.36	30.3	1750	199	298
W24×76	**200**	**499**	**750**	**307**	**462**	**15.0**	**22.5**	**6.78**	**19.6**	**2100**	**210**	**316**
W16×100	198	494	743	306	459	7.90	11.9	8.87	32.7	1490	199	298
W21×83	196	489	735	299	449	13.8	20.8	6.46	20.2	1830	221	331
W14×109	192	479	720	302	454	5.02	7.54	13.2	48.4	1240	150	226
W18×86	186	464	698	290	436	9.04	13.6	9.29	28.5	1070	177	265
W12×120	186	464	698	285	428	3.95	5.93	11.1	56.5	1530	186	279
W24×68	**177**	**442**	**664**	**269**	**404**	**14.1**	**21.2**	**6.61**	**18.8**	**1830**	**197**	**295**
W16×89	175	437	656	271	407	7.74	11.6	8.80	30.2	1300	176	264
W14×99[f]	173	430	646	274	412	4.89	7.35	13.5	45.3	1110	137	206
W21×73	172	429	645	264	396	12.9	19.4	6.39	19.2	1600	193	290
W12×106	164	409	615	253	381	3.93	5.90	11.0	50.7	933	157	236
W18×76	163	407	611	255	383	8.49	12.8	9.22	27.1	1330	155	232
W21×68	**160**	**399**	**600**	**245**	**368**	**12.5**	**18.8**	**6.36**	**18.7**	**1480**	**182**	**273**
W14×90[f]	157	382	573	250	375	4.80	7.22	15.2	42.6	999	123	185
W24x62	**153**	**382**	**574**	**229**	**344**	**16.0**	**24.1**	**4.87**	**14.4**	**1550**	**204**	**306**
W16×77	150	374	563	234	352	7.34	11.0	8.72	27.8	1110	150	225
W12×96	147	367	551	229	344	3.87	5.81	10.9	46.6	833	140	210
W10×112	147	367	551	220	331	2.68	4.02	9.47	64.3	716	172	257
W18×71	146	364	548	222	333	10.5	15.7	6.00	19.6	1170	183	274
W21×62	**144**	**359**	**540**	**222**	**333**	**11.6**	**17.4**	**6.25**	**18.1**	**1330**	**168**	**252**
W14×82	139	347	521	215	323	5.43	8.16	8.76	33.1	881	146	219
W24×55[v]	**134**	**334**	**503**	**199**	**299**	**14.8**	**22.2**	**4.73**	**13.9**	**1350**	**167**	**251**
W18×65	133	332	499	204	307	9.92	14.9	5.97	18.8	1070	165	248
W12×87	132	329	495	206	310	3.84	5.76	10.8	43.0	740	129	194
W16×67	130	324	488	204	307	6.91	10.4	8.69	26.1	954	129	194
W10×100	130	324	488	196	294	2.66	4.01	9.36	57.7	623	151	226
W21×57	129	322	484	194	291	13.4	20.1	4.77	14.3	1170	171	256

ASD	LRFD
$\Omega_b = 1.67$ $\Omega_v = 1.50$	$\phi_b = 0.90$ $\phi_v = 1.00$

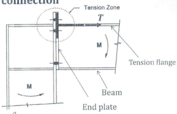
[f] Shape exceeds compact limit for flexure with $F_y = 50$ ksi.

[v] Shape does not meet the h/t_w limit for shear in Specification Section G2.1a with $F_y = 50$ ksi, $\Omega_v = 1.67$, $\phi_v = 0.90$.

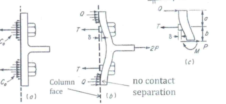
Extended end-plate moment connection

Non-seismic application

Behavior of endplate in tension zone under flexure.



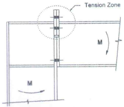
Thin endplate behavior

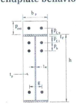


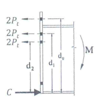
Endplate is thin and undergoes bending. This causes development of prying force Q.

Extended end-plate moment connection

Non-seismic application: Thick endplate behavior







Determination of bolt diameter

Moment equilibrium:

$$2P_t d_0 + 2P_t d_1 + 2P_t d_2 = M_u$$

$$\Rightarrow 2P_t \Sigma d_n = M_u$$

$$\Rightarrow 2(\phi \frac{\pi}{4} d_b{}^2 F_t)\, \Sigma d_n = M_u$$

$$d_b = \sqrt{\frac{2M_u}{\pi \phi F_t \sum d_n}}$$

Extended end-plate moment connection

Non-seismic application: Thick endplate behavior

Determination of endplate thickness

End plate thickness, $t_p = \sqrt{\dfrac{1.11\gamma_r \phi M_{np}}{\phi_b F_{py} Y}}$

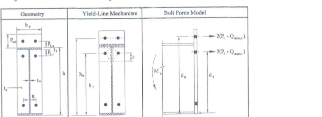
Where, $\phi_b = 0.9$,
$\gamma_r = 1.0$ **for extended end plate,**
F_{py} **= Endplate yield strength,**
Y **= yield line mechanism parameter,**
ϕM_{np} **= connection strength based on bolt tension limit state.**
$= \phi[2P_t \Sigma d_n]$, **where** $P_t = \frac{\pi}{4} {d_b}^2 F_t$ **and** $\phi = 0.75$
and $F_t = 90$ **ksi for A325 and 113 ksi for A490 bolts.**
ASTM Bolts diameters are: $^1/_2, {}^5/_8, {}^3/_4, {}^7/_8, 1, 1^1/_8, 1^1/_4, 1^3/_8, 1^1/_2$ **inch**

Extended end-plate moment connection

Non-seismic application: Thick endplate behavior

Y = yield line mechanism parameter: Four bolt unstiffened

Geometry	Yield-Line Mechanism	Bolt Force Model

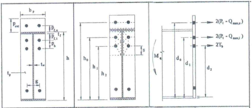


End-Plate Yield	$\phi M_n = \phi_b M_{pl} = \phi_b F_{py} t_p^2 Y$ $Y = \frac{b_p}{2}\left[h_1\left(\frac{1}{p_{f,i}} + \frac{1}{s}\right) + h_0\left(\frac{1}{p_{f,o}}\right) - \frac{1}{2}\right] + \frac{2}{g}\left[h_1\left(p_{f,i} + s\right)\right]$ Note: Use $p_{f,i} = s$, if $p_{f,i} > s$ $s = \frac{1}{2}\sqrt{b_p g}$ $\phi_b = 0.90$

Extended end-plate moment connection

Non-seismic application: Thick endplate behavior

Y = yield line mechanism parameter: Six bolt (1/2 rows) unstiffened

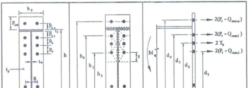


End-Plate Yield	$\phi M_n = \phi_b M_{pl} = \phi_b F_{py} t_p^2 Y$ $Y = \frac{b_p}{2}\left[h_1\left(\frac{1}{p_{f,i}}\right) + h_2\left(\frac{1}{s}\right) + h_0\left(\frac{1}{p_{f,o}}\right) - \frac{1}{2}\right] + \frac{2}{g}\left[h_1\left(p_{f,i} + 0.75p_b\right) + h_2\left(s + 0.25p_b\right)\right] + \frac{g}{2}$ $s = \frac{1}{2}\sqrt{b_p g}$ $\phi_b = 0.90$ Note: Use $p_{f,i} = s$, if $p_{f,i} > s$

Extended end-plate moment connection

Non-seismic application: Thick endplate behavior

Y = yield line mechanism parameter: Eight bolt (1/3 rows) unstiffened



End-Plate Yield	$\phi M_n = \phi_b M_{pl} = \phi_b F_{py} t_p^2 Y$ $Y = \frac{b_p}{2}\left[h_1\left(\frac{1}{p_{f,i}}\right) + h_3\left(\frac{1}{s}\right) + h_0\left(\frac{1}{p_{f,o}}\right) - \frac{1}{2}\right] + \frac{2}{g}\left[h_1\left(p_{f,i} + 1.5p_b\right) + h_3\left(s + 0.5p_b\right)\right] + \frac{g}{2}$ $s = \frac{1}{2}\sqrt{b_p g}$ $\phi_b = 0.90$ Note: Use $p_{f,i} = s$, if $p_{f,i} > s$

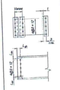
Beam	F_y = 50 ksi F_u = 65 ksi
Angle	F_y = 36 ksi F_u = 58 ksi

Table 10-1 (continued)
All-Bolted Double-Angle Connections

3/4-in. Bolts

Bolt and Angle Available Strength, kips

5 Rows	Bolt Group	Thread Cond.	Hole Type	Angle Thickness, in. 1/4 ASD	1/4 LRFD	5/16 ASD	5/16 LRFD	3/8 ASD	3/8 LRFD	1/2 ASD	1/2 LRFD
W30, 27, 24, 21, 18	Group A	N	STD	83.3	125	104	156	119	179	119	179
		X	STD	83.3	125	104	156	125	187	150	225
		SC Class A	STD	63.3	94.9	63.3	94.9	63.3	94.9	63.3	94.9
			OVS	53.9	80.7	53.9	80.7	53.9	80.7	53.9	80.7
			SSLT	63.3	94.9	63.3	94.9	63.3	94.9	63.3	94.9
		SC Class B	STD	83.3	125	104	156	105	158	105	158
			OVS	82.4	124	89.9	134	89.9	134	89.9	134
			SSLT	82.0	123	102	154	105	158	105	158
	Group B	N	STD	83.3	125	104	156	125	187	150	225
		X	STD	83.3	125	104	156	125	187	167	250
		SC Class A	STD	79.1	119	79.1	119	79.1	119	79.1	119
			OVS	67.4	101	67.4	101	67.4	101	67.4	101
			SSLT	79.1	119	79.1	119	79.1	119	79.1	119
		SC Class B	STD	83.3	125	104	156	125	187	132	198
			OVS	82.4	124	103	155	112	168	112	168
			SSLT	82.0	123	102	154	123	184	132	198



Beam Web Available Stren th per Inch Thic ness, ips/in.

Hole Type		STD				OVS				SSLT			
		L_{eh}*, in.											
		1 1/2		1 3/4		1 1/2		1 3/4		1 1/2		1 3/4	
L_{ev}, in.		ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
Coped at Top Flange Only	1 1/4	208	312	216	324	195	293	203	305	205	307	213	320
	1 3/8	210	316	219	328	197	296	206	308	207	311	216	323
	1 1/2	213	319	221	332	200	300	208	312	210	315	218	327
	1 5/8	215	323	223	335	202	303	210	316	212	318	220	331
	2	223	334	231	346	210	314	218	327	220	329	228	342
	3	242	363	250	375	229	344	237	356	239	359	247	371
Coped at Both Flanges	1 1/4	197	296	197	296	185	278	185	278	197	296	197	296
	1 3/8	202	303	202	303	190	285	190	285	202	303	202	303
	1 1/2	207	311	207	311	195	293	195	293	207	311	207	311
	1 5/8	212	318	212	318	200	300	200	300	212	318	212	318
	2	223	334	227	340	210	314	215	322	220	329	227	340
	3	242	363	250	375	229	344	237	356	239	359	247	371
Uncoped		293	439	293	439	293	439	293	439	293	439	293	439

Support Available Strength per Inch Thickness, ips/in.

Hole Type	ASD	LRFD
STD/ OVS/ SSLT	585	878

Notes:
STD = Standard holes
OVS = Oversized holes
SSLT = Short-slotted holes transverse to direction of load
N = Threads included
X = Threads excluded
SC = Slip critical

* Tabulated values include 1/4-in. reduction in end distance, L_{eh}, to account for possible underrun in beam length.

Note: Slip-critical bolt values assume no more than one filler has been provided or bolts have been added to distribute loads in the fillers.