University of Asia Pacific
Department of Civil Engineering
Final Examination Spring 2013
Program: B.Sc Engineering (Civil)

Course Title: Structural Engineering VI (Design of Steel Structures) Course Code: CE 417
Time: 2 hours Full Marks: 50

The figures in the margin indicate full marks.
Assume reasonable values for any missing data. Annexures are provided to facilitate design.

There are EIGHT questions. Answer any SIX questions

1. Write the equation for the stress-strain behaviour in tension of the 18x1 inch plate with the residual stress shown in Fig. 1 at an imposed tensile strain of 0.0013 in./in. What is the tangent modulus at this strain? Given: F_y=36 ksi; E=30000 ksi. 8 ⅓

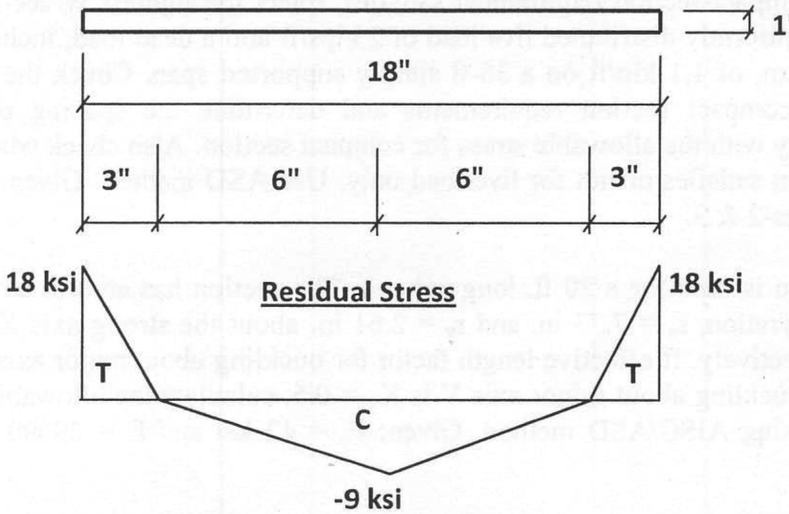


Fig. 1

2. Determine the effective length coefficients for the columns of the frame shown in Fig. 2. The moments of inertia in $inch^4$ for the columns and beams are shown in the figure. Annexure-1 provides necessary nomographs. 8 ⅓

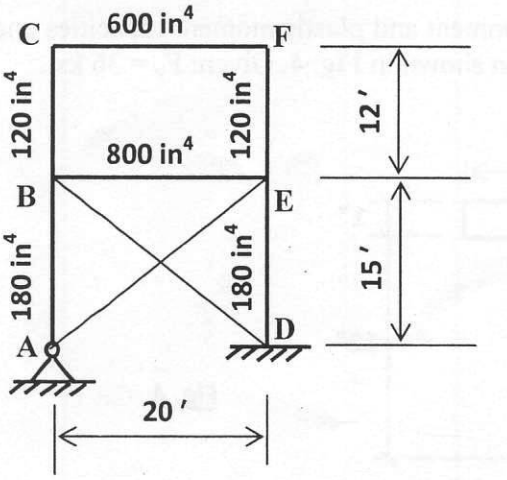
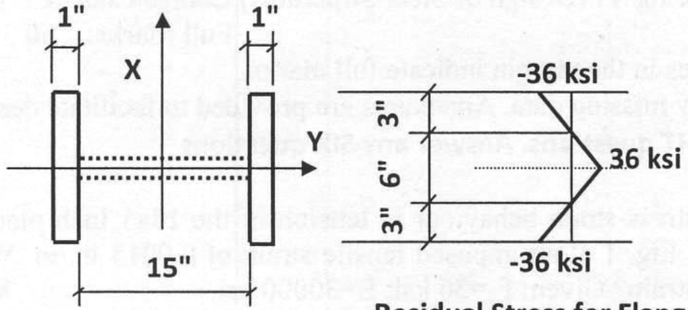


Fig. 2

3. The residual stress distribution in flanges of a webless H section for a column is shown in Fig. 3. Determine the values of $I_{x,eff}$ and $I_{y,eff}$ (effective moments of inertia about x and y axes) and critical slenderness ratio, L/r_x and L/r_y for strong and weak axis buckling, if the column with the given section buckles at an imposed uniform compressive strain of –0.0016 in./in. Given: F_y = 60 ksi and E = 30000 ksi. 8 ⅓



Residual Stress for Flanges

Fig. 3

4. Assuming that compact-section requirement satisfies, select the lightest W section for a beam to carry a uniformly distributed live load of 2 kips/ft and a dead load, including the weight of the beam, of 1.1 kip/ft on a 36-ft simply supported span. Check the selected section for full compact section requirements and determine the spacing of lateral bracings to comply with the allowable stress for compact section. Also check whether the deflection criterion satisfies or not for live load only. Use ASD method. Given: F_y = 36 ksi. See Annexures-2 & 3. 8 ⅓

5. A W18x76 section is used for a 20 ft. long column. The section has an area of 22.3 in^2 and a radius of gyration, r_x = 7.73 in. and r_y = 2.61 in. about the strong axis X and the weak axis Y respectively. If effective length factor for buckling about major axis X is K_x = 1 and that for buckling about minor axis Y is K_y = 0.5, calculate the allowable load P for the column using AISC/ASD method. Given: F_y = 42 ksi and E = 29000 ksi. See Annexure-4. 8 ⅓

6. Using LRFD method, calculate the design strength of a W24x76 section for a 20 ft. long column. The section has an area of 22.4 in^2 and radius of gyration, r_x = 9.69 in. and r_y = 1.92 in. about the strong axis X and the weak axis Y respectively. Given: Effective length factor for buckling about major axis X is K_x = 2 and that for buckling about minor axis Y is K_y = 0.7; F_y = 42 ksi and E = 29000 ksi. See Annexure-5. 8 ⅓

7. Compute the yield moment and plastic moment capacities and shape factor for major axis bending of the section shown in Fig. 4. Given: F_y = 36 ksi. 8 ⅓

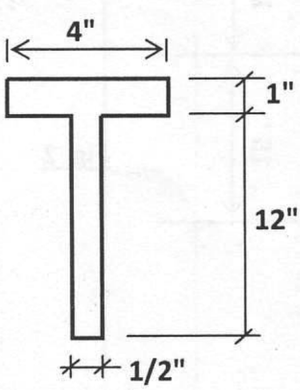


Fig. 4

8. Using AISC/ASD method, determine the block shear allowable load for the joint shown in Fig. 5. Fasteners are 3/4-in A-325 bolts in standard holes. All plates are A36 steel. Allowable stress in shear on net shear area = $0.3F_u$ & allowable stress in tension on net tension area = $0.5F_u$. 8 ⅓

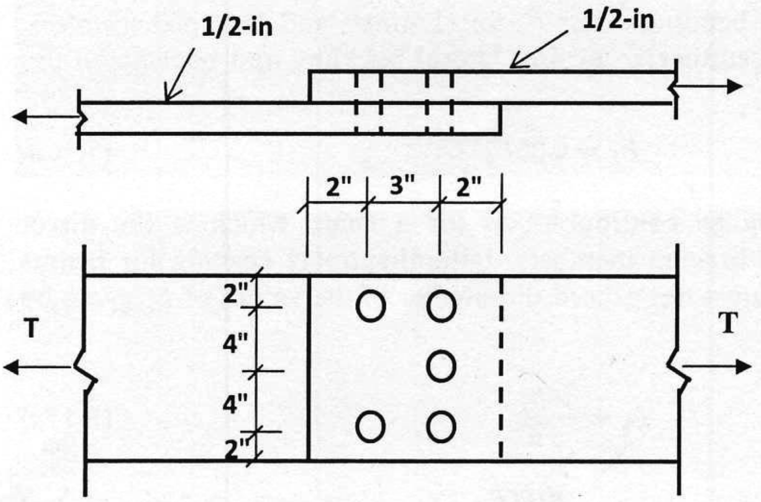
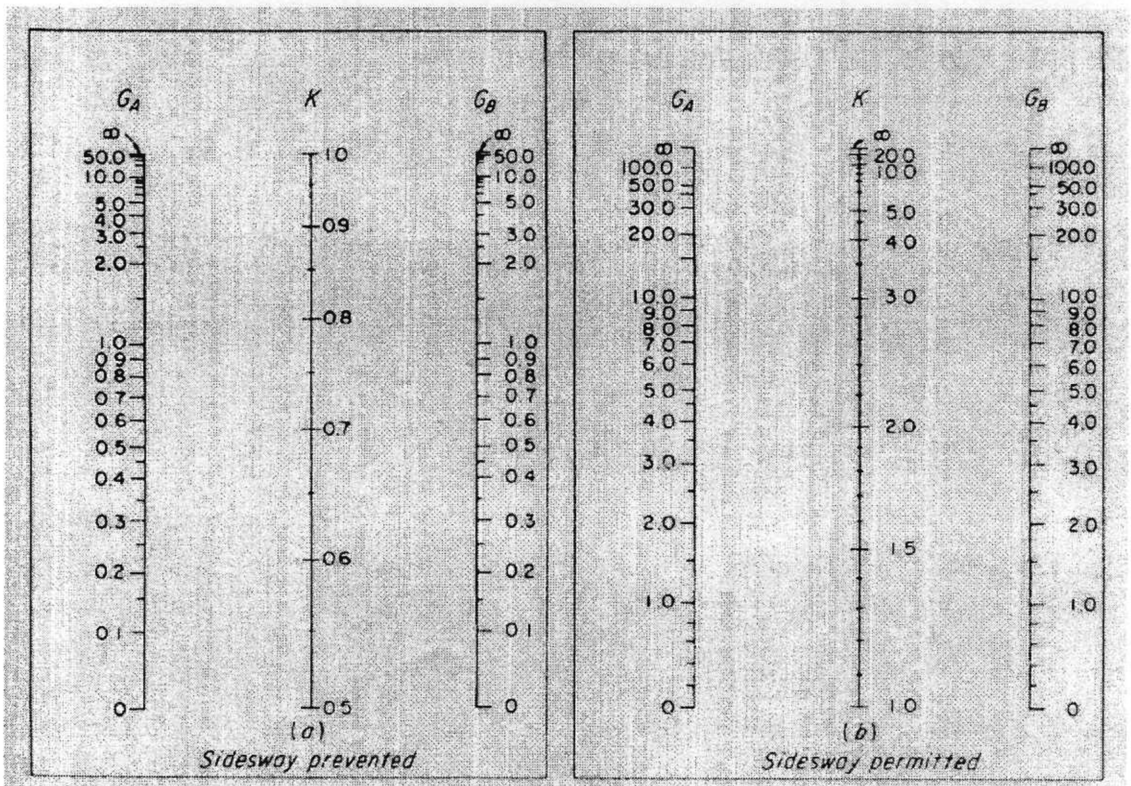


Fig. 5

ANNEXURE-1



Nomograph for effective length of columns.

ANNEXURE-2

Specification Formulas

AISC/ASD. The allowable bending stress F_b for channels and I-shaped members of steels with $F_y \le 65$ ksi, supported against lateral buckling and bent about the major axis, are as follows:

Compact section: $$F_b = 0.66F_y \qquad (5\text{-}16a)$$

Lateral support may be continuous, as for a beam which is the direct support of a floor, or by bracing members. Lateral-support spacing for beams designed for $F_b = 0.66F_y$ must not exceed the smaller of the values of L_c given by the following:

$$L_c = \frac{76b_f}{\sqrt{F_y}} \qquad (5\text{-}17a)$$

$$L_c = \frac{20{,}000}{F_y d/A_f} \qquad (5\text{-}17b)$$

DEFLECTION CRITERIA FOR LIVE LOAD STRESS F_b:

$$\frac{L}{d} \le \frac{480}{F_b}$$

ANNEXURE-2 (Contd.)

TABLE 5-3
Limiting values of beam flange and web slenderness

Type of element	Ratio	AISC/ASD Compact	AISC/ASD Noncompact	AISC/LRFD Compact	AISC/LRFD Noncompact	AREA	AASHTO
Flange of rolled I or channel	$\frac{b}{t}$	$\frac{65^{a}}{\sqrt{F_y}}$	$\frac{95^{a}}{\sqrt{F_y}}$	$\frac{65^{a}}{\sqrt{F_y}}$	$\frac{141^{a,b}}{\sqrt{F_{yw} - 10}}$	$\frac{2300^{c}}{\sqrt{F_y, \text{psi}}}$	$\frac{3250^{d,e}}{\sqrt{f, \text{psi}}}$
Flange of welded I	$\frac{b}{t}$	$\frac{65^{a}}{\sqrt{F_y}}$	$\frac{95^{a}}{\sqrt{F_y/k_c}}$	$\frac{65^{a}}{\sqrt{F_{yf}}}$	$\frac{106^{a}}{\sqrt{F_{yw} - 16.5}}$	$\frac{2300^{c}}{\sqrt{F_y, \text{psi}}}$	$\frac{3250^{d,e}}{\sqrt{f, \text{psi}}}$
Flange of box	$\frac{b}{t}$	$\frac{190}{\sqrt{F_y}}$	$\frac{238}{\sqrt{F_y}}$	$\frac{190}{\sqrt{F_y}}$	$\frac{238}{\sqrt{F_y - F_r}}$	$\frac{7500}{\sqrt{F_y, \text{psi}}}$	$\frac{5000^{e}}{\sqrt{f, \text{psi}}}$
Web[f] of I	$\frac{d^{g}}{t}$	$\frac{640}{\sqrt{F_y}}$					
Web[f] of I	$\frac{h^{h,i}}{t}$	...	$\frac{760}{\sqrt{F_b}}$	$\frac{640}{\sqrt{F_y}}$	$\frac{970}{\sqrt{F_y}}$		

F_y in ksi except where noted.
F_{yf} = yield stress of flange.
F_w = yield stress of web.
F_b = allowable bending stress for beams with no axial force.
F_r = residual stress = 10 ksi for rolled shapes, 16.5 ksi for welded shapes.
$k_c = 4.05/(h/t)^{0.46}$ if $h/t > 70$; otherwise $k_c = 1$. See Art. 5-8.
[a] b = half width of flange.
[b] $106/\sqrt{F_{yw} - 16.5}$ for welded shapes.
[c] b = distance from free edge of flange to fillet.
[d] b = width of flange.
[e] f = service-load stress.
[f] Webs in flexure. See Art. 5-15 for flexure and axial compression.
[g] d = depth of beam.
[h] h = clear distance between flanges of rolled, built-up, or formed sections (AISC/ASD).
[i] h = twice the distance from the neutral axis to the nearest line of fasteners at the compression flange or to the inside face of the

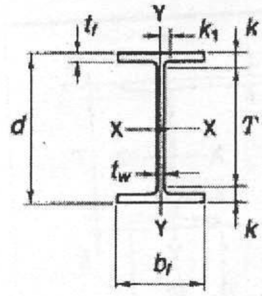
ANNEXURE-3

S_x ALLOWABLE STRESS DESIGN SELECTION TABLE

For shapes used as beams

F_y = 50 ksi			S_x	Shape	Depth d	F_y'	F_y = 36 ksi		
L_c	L_u	M_R					L_c	L_u	M_R
Ft	Ft	Kip-ft	In.^{3}		In.	Ksi	Ft	Ft	Kip-ft
10.3	**11.1**	**1230**	**448**	**W 33×141**	**33¼**	**—**	**12.2**	**15.4**	**887**
8.8	**11.0**	**1210**	**439**	**W 36×135**	**35½**	**—**	**12.3**	**13.0**	**869**
9.4	13.4	1200	436	W 30×148	30⅝	—	11.1	18.7	863
10.3	35.5	1150	419	W 18×211	20⅝	—	12.2	49.3	830
11.2	27.1	1150	417	W 21×182	22¾	—	13.2	37.6	826
11.6	21.1	1140	414	W 24×162	25	—	13.7	29.3	820
12.5	16.6	1130	411	W 27×146	27⅜	—	14.7	23.0	814
9.9	**10.8**	**1120**	**406**	**W 33×130**	**33⅛**	**—**	**12.1**	**13.8**	**804**
9.4	11.6	1050	380	W 30×132	30¼	—	11.1	16.1	752
11.1	25.1	1050	380	W 21×166	22½	—	13.1	34.8	752
10.3	32.7	1050	380	W 18×192	20⅜	—	12.1	45.4	752
11.6	18.9	1020	371	W 24×146	24¾	—	13.6	26.3	735
8.6	**10.7**	**987**	**359**	**W 33×118**	**32⅞**	**—**	**12.0**	**12.6**	**711**
9.4	10.8	976	355	W 30×124	30⅛	—	11.1	15.0	703
9.0	13.3	949	345	W 27×129	27⅝	—	10.6	18.4	683
10.2	30.0	946	344	W 18×175	20	—	12.0	41.7	681
9.4	**9.9**	**905**	**329**	**W 30×116**	**30**	**—**	**11.1**	**13.8**	**651**
11.5	16.8	905	329	W 24×131	24½	—	13.6	23.4	651
11.2	21.8	905	329	W 21×147	22	—	13.2	30.3	651
10.1	27.5	853	310	W 18×158	19¾	—	11.9	38.3	614
8.9	**9.8**	**822**	**299**	**W 30×108**	**29⅞**	**—**	**11.1**	**12.3**	**592**
9.0	11.5	822	299	W 27×114	27¼	—	10.6	15.9	592
11.1	19.6	811	295	W 21×132	21⅞	—	13.1	27.2	584
11.5	14.9	800	291	W 24×117	24¼	—	13.5	20.8	576
10.0	25.3	776	282	W 18×143	19½	—	11.8	35.1	558
11.1	18.3	751	273	W 21×122	21⅝	—	13.1	25.4	541
7.9	**9.7**	**740**	**269**	**W 30× 99**	**29⅝**	**—**	**10.9**	**11.4**	**533**
9.0	10.2	734	267	W 27×102	27⅛	—	10.6	14.2	529
11.4	13.2	710	258	W 24×104	24	58.5	13.5	18.4	511
10.0	23.1	704	256	W 18×130	19¼	—	11.8	32.2	507
11.1	16.8	685	249	W 21×111	21½	—	13.0	23.3	493
7.2	**9.6**	**674**	**245**	**W 30× 90**	**29½**	**58.1**	**10.0**	**11.4**	**485**
8.1	12.0	674	245	W 24×103	24½	—	9.5	16.7	485
8.9	9.5	668	243	W 27× 94	26⅞	—	10.5	12.8	481
10.1	21.0	635	231	W 18×119	19	—	11.9	29.1	457
11.0	15.4	624	227	W 21×101	21⅜	—	13.0	21.3	449
8.1	10.9	611	222	W 24× 94	24¼	—	9.6	15.1	440
8.0	**9.4**	**586**	**213**	**W 27× 84**	**26¾**	**—**	**10.5**	**11.0**	**422**
10.0	18.7	561	204	W 18×106	18¾	—	11.8	26.0	404
8.1	**9.6**	**539**	**196**	**W 24× 84**	**24⅛**	**—**	**9.5**	**13.3**	**388**
7.5	12.1	528	192	W 21× 93	21⅝	—	8.9	16.8	380
13.1	31.7	523	190	W 14×120	14½	—	15.5	44.1	376
10.0	17.4	517	188	W 18× 97	18⅝	—	11.8	24.1	372

ANNEXURE-3 (Contd.)

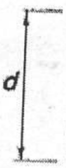


W SHAPES
Dimensions

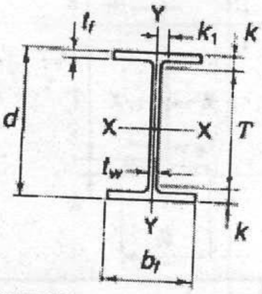
Designation	Area A	Depth d		Web			Flange				Distance		
				Thickness t_w		$\frac{t_w}{2}$	Width b_f		Thickness t_f		T	k	k_1
	In.^{2}	In.		In.		In.	In.		In.		In.	In.	In.
W 30×148[b]	43.5	30.67	30 5/8	0.650	5/8	5/16	10.480	10 1/2	1.180	1 3/16	26 3/4	2	1
×132	38.9	30.31	30 1/4	0.615	5/8	5/16	10.545	10 1/2	1.000	1	26 3/4	1 3/4	1 1/16
×124	36.5	30.17	30 1/8	0.585	9/16	5/16	10.515	10 1/2	0.930	15/16	26 3/4	1 11/16	1
×116	34.2	30.01	30	0.565	9/16	5/16	10.495	10 1/2	0.850	7/8	26 3/4	1 5/8	1
×108	31.7	29.83	29 7/8	0.545	9/16	5/16	10.475	10 1/2	0.760	3/4	26 3/4	1 9/16	1
× 99	29.1	29.65	29 5/8	0.520	1/2	1/4	10.450	10 1/2	0.670	11/16	26 3/4	1 7/16	1
× 90	26.4	29.53	29 1/2	0.470	1/2	1/4	10.400	10 3/8	0.610	9/16	26 3/4	1 5/16	1
W 27×539[a]	158.0	32.52	32 1/2	1.970	2	1	15.255	15 1/4	3.540	3 9/16	24	4 1/4	1 5/8
×494[a]	145.0	31.97	32	1.810	1 13/16	15/16	15.095	15 1/8	3.270	3 1/4	24	4	1 9/16
×448[a]	131.0	31.42	31 3/8	1.650	1 5/8	13/16	14.940	15	2.990	3	24	3 11/16	1 1/2
×407[a]	119.0	30.87	30 7/8	1.520	1 1/2	3/4	14.800	14 3/4	2.720	2 3/4	24	3 7/16	1 7/16
×368[a]	108.0	30.39	30 3/8	1.380	1 3/8	11/16	14.665	14 5/8	2.480	2 1/2	24	3 3/16	1 5/16
×336[a]	98.7	30.00	30	1.260	1 1/4	5/8	14.545	14 1/2	2.280	2 1/4	24	3	1 5/16
×307[a]	90.2	29.61	29 5/8	1.160	1 3/16	5/8	14.445	14 1/2	2.090	2 1/16	24	2 13/16	1 1/4
×281[a]	82.6	29.29	29 1/4	1.060	1 1/16	9/16	14.350	14 3/8	1.930	1 15/16	24	2 5/8	1 3/16
×258	75.7	28.98	29	0.980	1	1/2	14.270	14 1/4	1.770	1 3/4	24	2 1/2	1 1/8
×235	69.1	28.66	28 5/8	0.910	15/16	1/2	14.190	14 1/4	1.610	1 5/8	24	2 5/16	1 1/8
×217	63.8	28.43	28 3/8	0.830	13/16	7/16	14.115	14 1/8	1.500	1 1/2	24	2 3/16	1 1/16
×194	57.0	28.11	28 1/8	0.750	3/4	3/8	14.035	14	1.340	1 5/16	24	2 1/16	1
×178	52.3	27.81	27 3/4	0.725	3/4	3/8	14.085	14 1/8	1.190	1 3/16	24	1 7/8	1 1/16
×161	47.4	27.59	27 5/8	0.660	11/16	3/8	14.020	14	1.080	1 1/16	24	1 13/16	1
×146	42.9	27.38	27 3/8	0.605	5/8	5/16	13.965	14	0.975	1	24	1 11/16	1
W 27×129[b]	37.8	27.63	27 5/8	0.610	5/8	5/16	10.010	10	1.100	1 1/8	24	1 13/16	15/16
×114	33.5	27.29	27 1/4	0.570	9/16	5/16	10.070	10 1/8	0.930	15/16	24	1 5/8	15/16
×102	30.0	27.09	27 1/8	0.515	1/2	1/4	10.015	10	0.830	13/16	24	1 9/16	15/16
× 94	27.7	26.92	26 7/8	0.490	1/2	1/4	9.990	10	0.745	3/4	24	1 7/16	15/16
× 84	24.8	26.71	26 3/4	0.460	7/16	1/4	9.960	10	0.640	5/8	24	1 3/8	15/16

[a]For application refer to Notes in Table 2.
[b]Heavier shapes in this series are available from some producers.
Shapes in shaded rows are not available from domestic producers.

ANNEXURE-3 (Contd.)



W SHAPES
Properties



Designation	Nominal Wt. per Ft (Lb.)	Compact Section Criteria: $\frac{b_f}{2t_f}$	F_y' (Ksi)	$\frac{d}{t_w}$	F_y''' (Ksi)	r_T (In.)	$\frac{d}{A_f}$	Elastic Properties, Axis X-X: I (In.^{4})	S (In.^{3})	r (In.)	Axis Y-Y: I (In.^{4})	S (In.^{3})	r (In.)	Plastic Modulus: Z_x (In.^{3})	Z_y (In.^{3})
W 30×148[b]	148	4.4	—	47.2	29.7	2.70	2.48	6680	436	12.4	227	43.3	2.28	500	68.0
×132	132	5.3	—	49.3	27.2	2.68	2.87	5770	380	12.2	196	37.2	2.25	437	58.4
×124	124	5.7	—	51.6	24.8	2.66	3.09	5360	355	12.1	181	34.4	2.23	408	54.0
×116	116	6.2	—	53.1	23.4	2.64	3.36	4930	329	12.0	164	31.3	2.19	378	49.2
×108	108	6.9	—	54.7	22.0	2.61	3.75	4470	299	11.9	146	27.9	2.15	346	43.9
× 99	99	7.8	—	57.0	20.3	2.57	4.23	3990	269	11.7	128	24.5	2.10	312	38.6
× 90	90	8.5	58.1	62.8	16.7	2.56	4.65	3620	245	11.7	115	22.1	2.09	283	34.7
W 27×539[a]	539	2.2	—	16.5	—	4.10	0.60	25500	1570	12.7	2110	277	3.86	1880	437
×494[a]	494	2.3	—	17.7	—	4.05	0.65	22900	1440	12.6	1890	260	3.61	1710	394
×448[a]	448	2.5	—	19.0	—	4.01	0.70	20400	1300	12.5	1670	224	3.57	1530	351
×407[a]	407	2.7	—	20.3	—	3.96	0.77	18100	1170	12.3	1480	200	3.52	1380	313
×368[a]	368	3.0	—	22.0	—	3.93	0.84	16100	1060	12.2	1310	179	3.48	1240	279
×336[a]	336	3.2	—	23.8	—	3.89	0.90	14500	970	12.1	1170	161	3.45	1130	252
×307[a]	307	3.5	—	25.5	—	3.86	0.98	13100	884	12.0	1050	146	3.42	1020	227
×281[a]	281	3.7	—	27.6	—	3.84	1.06	11900	811	12.0	953	133	3.40	933	206
×258	258	4.0	—	29.6	—	3.81	1.15	10800	742	11.9	859	120	3.37	850	187
×235	235	4.4	—	31.5	—	3.78	1.25	9660	674	11.8	768	108	3.33	769	168
×217	217	4.7	—	34.3	56.3	3.76	1.34	8870	624	11.8	704	99.8	3.32	708	154
×194	194	5.2	—	37.5	47.0	3.74	1.49	7820	556	11.7	618	88.1	3.29	628	136
×178	178	5.9	—	38.4	44.9	3.72	1.66	6990	502	11.6	555	78.8	3.26	567	122
×161	161	6.5	—	41.8	37.8	3.70	1.82	6280	455	11.5	497	70.9	3.24	512	109
×146	146	7.2	—	45.3	32.2	3.68	2.01	5630	411	11.4	443	63.5	3.21	461	97.5
W 27×129[b]	129	4.5	—	45.3	32.2	2.59	2.51	4760	345	11.2	184	36.8	2.21	395	57.6
×114	114	5.4	—	47.9	28.8	2.58	2.91	4090	299	11.0	159	31.5	2.18	343	49.3
×102	102	6.0	—	52.6	23.9	2.56	3.26	3620	267	11.0	139	27.8	2.15	305	43.4
× 94	94	6.7	—	54.9	21.9	2.53	3.62	3270	243	10.9	124	24.8	2.12	278	38.8
× 84	84	7.8	—	58.1	19.6	2.49	4.19	2850	213	10.7	106	21.2	2.07	244	33.2

[a]For appli
[b]Heavier s
Shapes in

ANNEXURE-4

The AISC/ASD formulas for allowable stress F_a on axially loaded compression members are

$$F_a = \begin{cases} \dfrac{F_y\left[1 - \dfrac{1}{2}\left(\dfrac{KL/r}{C_c}\right)^2\right]}{\dfrac{5}{3} + \dfrac{3}{8}\dfrac{KL/r}{C_c} - \dfrac{1}{8}\left(\dfrac{KL/r}{C_c}\right)^3} & \dfrac{KL}{r} \le C_c \qquad (4\text{-}17) \\[2ex] \dfrac{12\pi^2 E}{23(KL/r)^2} = \dfrac{149{,}000}{(KL/r)^2} & \dfrac{KL}{r} \ge C_c \qquad (4\text{-}18) \end{cases}$$

where K is the effective-length coefficient (Art. 4-5) and

$$C_c = \pi\sqrt{\frac{2E}{F_y}}$$

ANNEXURE-5

The AISC/LRFD design strength of columns is $\phi_c P_n$, where $\phi_c = 0.85$ and $P_n = A_g F_{cr}$, with F_{cr} given by

$$F_{cr} = \begin{cases} 0.658^{\lambda_c^2} F_y & 0 \le \lambda_c < 1.5 \qquad (4\text{-}27) \\ \dfrac{0.877}{\lambda_c^2} F_y & \lambda_c > 1.5 \qquad (4\text{-}28) \end{cases}$$

in which

$$\lambda_c = \frac{KL}{r\pi}\sqrt{\frac{F_y}{E}}$$