4-2

University of Asia Pacific
Department of Civil Engineering
Final Examination Fall 2012
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. Calculate all the probable net widths and the controlling net area for the 14-inch wide by ½-inch thick plate with staggered holes to be used as a tension member as shown in Fig.1. Holes are for 3/4-in. diameter bolts. 8 ⅓

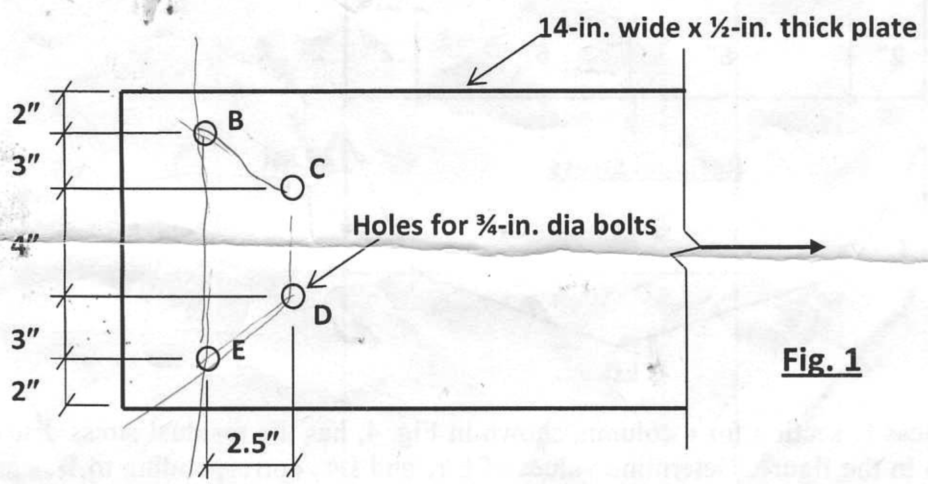


Fig. 1

2. Compute the yield moment and plastic moment capacities and shape factor for major axis (X-axis) bending of the I-section shown in Fig. 2. Given: F_y = 50 ksi. 8 ⅓

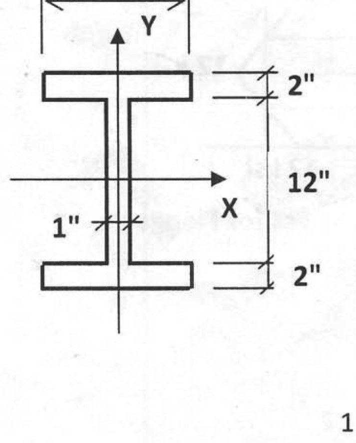


Fig. 2

$\frac{336+304}{16} = 40$

3. Select the lightest W section for a beam to carry a uniformly distributed live load of 2.4 kips/ft and a dead load, including the weight of the beam, of 1.2 kips/ft on a 32-ft simply supported span. Assume that the beam will be braced to satisfy compact-section requirements. What will be the least spacing of lateral bracings to satisfy the compact section requirements? Also check whether the deflection criterion is satisfied or not for live load only. Given: $F_y = 65$ ksi. See Annexures-1 & 2. 8 ⅓

4. Write the equation for the stress-strain behaviour in tension of the 16x1 inch plate with the residual stress shown in Fig. 3 at an imposed tensile strain of 0.0014 in./in. What is the tangent modulus at this strain? Given: F_y=36 ksi; E=30000 ksi. 8 ⅓

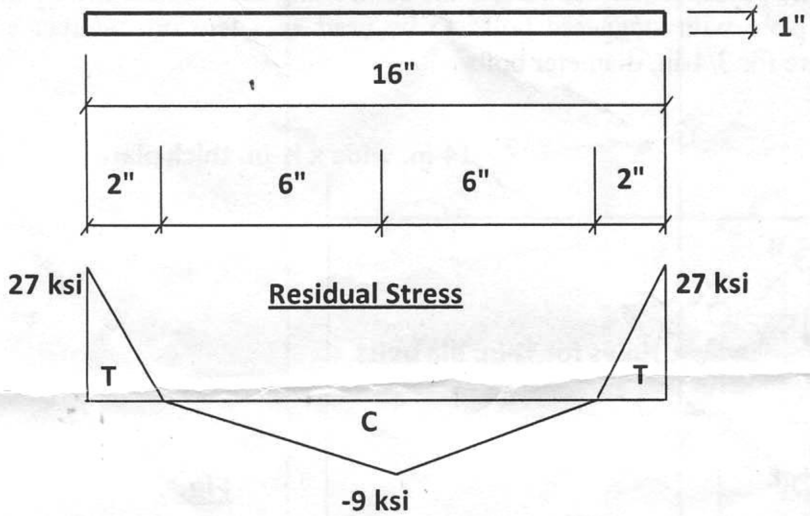


Fig. 3

5. The webless H section for a column, shown in Fig. 4, has the residual stress distribution as shown in the figure. Determine values of L/r_x and L/r_y corresponding to $I_{x,eff}$ and $I_{y,eff}$ (effective moments of inertia about x and y axes) respectively, if a column with the given section buckles at an imposed uniform compressive strain of –0.0012 in./in. Given: F_y = 36 ksi and E = 30000 ksi. 8 ⅓

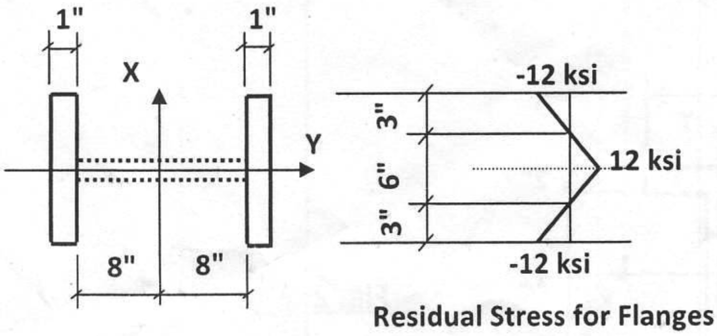


Fig. 4

6. A W10x54 section is used for a 18 ft. long column. The section has an area of 15.8 in^2 and a radius of gyration, r_y = 2.56 in. about the weak axis Y. If K=1 for both X and Y axes, using AISC/ASD method, check whether an axial load of 200 kip is safe for the column or not. Given: F_y = 36 ksi and E = 29000 ksi. See Annexure-3. 8 ⅓

7. A W14x38 section, with an area of 11.2 in^2 and a radius of gyration r_y = 1.55 in. about the weak axis Y, is to be used for a 10 ft. long column. If K=1 for both X and Y axes, using AISC/LRFD method, determine whether the column will be able to carry an axial dead load of 60 kip along with a live load of 150 kip. Given: F_y = 36 ksi and E = 29000 ksi. See Annexure-4. 8 ⅓

8. Determine the effective length coefficients for the columns of the frame shown in Fig. 5. The moments of inertia in $inch^4$ for the columns and beams are shown in the figure. Annexure-5 provides necessary nomographs. 8 ⅓

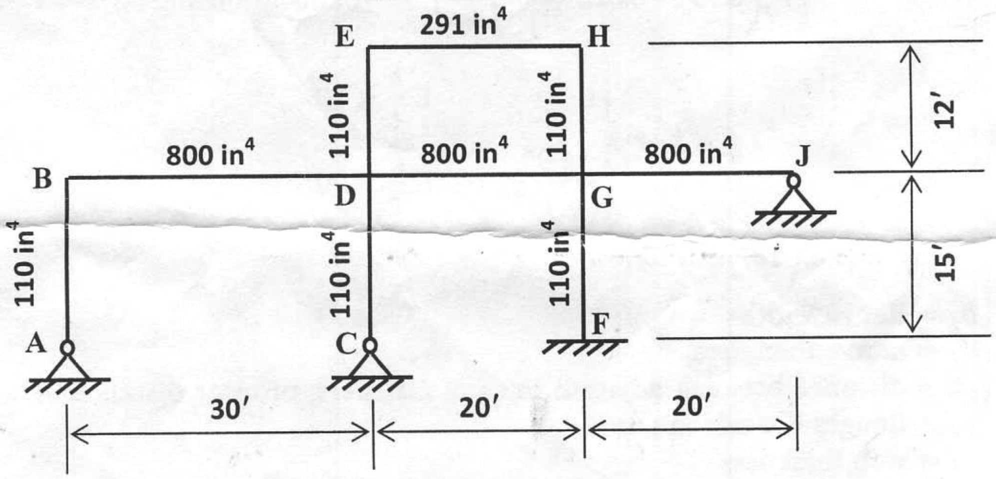


Fig. 5

1, 2,

ANNEXURE-1

Specification Formulas

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

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

Noncompact section: $$F_b = 0.60F_y \qquad (5\text{-}16b)$$

If $65/\sqrt{F_y} \leq b_f/2t_f \leq 95/\sqrt{F_y}$:

$$F_b = \begin{cases} F_y\left(0.79 - 0.002\dfrac{b_f}{2t_f}\sqrt{F_y}\right) & \text{(rolled shapes)} \quad (5\text{-}16c) \\ F_y\left(0.79 - 0.002\dfrac{b_f}{2t_f}\sqrt{\dfrac{F_y}{k_c}}\right) & \text{(built-up members)} \quad (5\text{-}16d) \end{cases}$$

where

$$k_c = \begin{cases} 1 & \text{if } \dfrac{h}{t} \leq 70 \\ \dfrac{4.05}{(h/t)^{0.46}} & \text{if } \dfrac{h}{t} > 70 \end{cases}$$

Notation in Eqs. (5-16) is as follows:

b_f = flange width
t_f = flange thickness
h = distance between adjacent lines of fasteners, or clear distance between flanges if welds are used
t = web thickness

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:

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

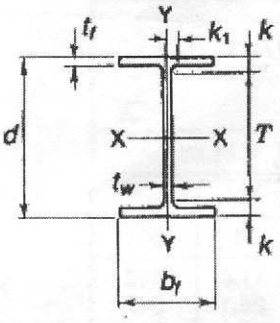
ANNEXURE-2

ALLOWABLE STRESS DESIGN SELECTION TABLE
For shapes used as beams

S_x

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
8.1	**8.5**	**484**	**176**	**W 24× 76**	**23⅞**	**—**	**9.5**	**11.8**	**348**
9.3	20.2	481	175	W 16×100	17	—	11.0	28.1	347
13.1	29.2	476	173	W 14×109	14⅜	58.6	15.4	40.6	343
7.5	10.9	470	171	W 21× 83	21⅜	—	8.8	15.1	339
9.9	15.5	457	166	W 18× 86	18⅜	—	11.7	21.5	329
13.0	26.7	432	157	W 14× 99	14⅛	48.5	15.4	37.0	311
9.3	18.0	426	155	W 16× 89	16¾	—	10.9	25.0	307
7.4	**8.5**	**424**	**154**	**W 24× 68**	**23¾**	**—**	**9.5**	**10.2**	**305**
7.4	9.6	415	151	W 21× 73	21¼	—	8.8	13.4	299
9.9	13.7	402	146	W 18× 76	18¼	64.2	11.6	19.1	289
13.0	24.5	393	143	W 14× 90	14	40.4	15.3	34.0	283
7.4	**8.9**	**385**	**140**	**W 21× 68**	**21⅛**	**—**	**8.7**	**12.4**	**277**
9.2	15.8	369	134	W 16× 77	16½	—	10.9	21.9	265
5.8	**6.4**	**360**	**131**	**W 24× 62**	**23¾**	**—**	**7.4**	**8.1**	**259**
7.4	**8.1**	**349**	**127**	**W 21× 62**	**21**	**—**	**8.7**	**11.2**	**251**
6.8	11.1	349	127	W 18× 71	18½	—	8.1	15.5	251
9.1	20.2	338	123	W 14× 82	14¼	—	10.7	28.1	244
10.9	26.0	325	118	W 12× 87	12½	—	12.8	36.2	234
6.8	10.4	322	117	W 18× 65	18⅜	—	8.0	14.4	232
9.2	13.9	322	117	W 16× 67	16⅜	—	10.8	19.3	232
5.0	**6.3**	**314**	**114**	**W 24× 55**	**23⅝**	**—**	**7.0**	**7.5**	**226**
9.0	18.6	308	112	W 14× 74	14⅛	—	10.6	25.9	222
5.9	6.7	305	111	W 21× 57	21	—	6.9	9.4	220
6.8	9.6	297	108	W 18× 60	18¼	—	8.0	13.3	214
10.8	24.0	294	107	W 12× 79	12⅜	62.6	12.8	33.3	212
9.0	17.2	283	103	W 14× 68	14	—	10.6	23.9	204
6.7	**8.7**	**270**	**98.3**	**W 18× 55**	**18⅛**	**—**	**7.9**	**12.1**	**195**
10.6	21.9	268	97.4	W 12× 72	12¼	52.3	12.7	30.5	193
5.6	**6.0**	**260**	**94.5**	**W 21× 50**	**20⅞**	**—**	**6.9**	**7.8**	**187**
6.4	10.3	254	92.2	W 16× 57	16⅜	—	7.5	14.3	183
9.0	15.5	254	92.2	W 14× 61	13⅞	—	10.6	21.5	183
6.7	**7.9**	**244**	**88.9**	**W 18× 50**	**18**	**—**	**7.9**	**11.0**	**176**
10.7	20.0	238	87.9	W 12× 65	12⅛	43.0	12.7	27.7	174
4.7	**5.9**	**224**	**81.6**	**W 21× 44**	**20⅝**	**—**	**6.6**	**7.0**	**162**
6.3	9.1	223	81.0	W 16× 50	16¼	—	7.5	12.7	160
5.4	6.8	217	78.8	W 18× 46	18	—	6.4	9.4	156
9.0	17.5	215	78.0	W 12× 58	12¼	—	10.6	24.4	154
7.2	12.7	214	77.8	W 14× 53	13⅞	—	8.5	17.7	154
6.3	8.2	200	72.7	W 16× 45	16⅛	—	7.4	11.4	144
9.0	15.9	194	70.6	W 12× 53	12	55.9	10.6	22.0	140
7.2	11.5	193	70.3	W 14× 48	13¾	—	8.5	16.0	139

ANNEXURE-2 (Contd.)

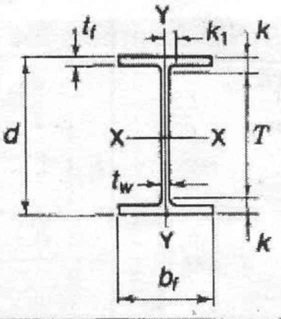


W SHAPES
Dimensions

Designation	Area A	Depth d		Web Thickness t_w		Web $\frac{t_w}{2}$	Flange Width b_f		Flange Thickness t_f		Distance T	Distance k	Distance k_1
	In.^{2}	In.		In.		In.	In.		In.		In.	In.	In.
W 24×492[a]	144.0	29.65	29 5/8	1.970	2	1	14.115	14 1/8	3.540	3 9/16	21	4 5/16	1 9/16
×450[a]	132.0	29.09	29 1/8	1.810	1 13/16	15/16	13.955	14	3.270	3 1/4	21	4 1/16	1 1/2
×408[a]	119.0	28.54	28 1/2	1.650	1 5/8	13/16	13.800	13 3/4	2.990	3	21	3 3/4	1 3/8
×370[a]	108.0	27.99	28	1.520	1 1/2	3/4	13.660	13 5/8	2.720	2 3/4	21	3 1/2	1 5/16
×335[a]	98.4	27.52	27 1/2	1.380	1 3/8	11/16	13.520	13 1/2	2.480	2 1/2	21	3 1/4	1 1/4
×306[a]	89.8	27.13	27 1/8	1.260	1 1/4	5/8	13.405	13 3/8	2.280	2 1/4	21	3 1/16	1 3/16
×279[a]	82.0	26.73	26 3/4	1.160	1 3/16	5/8	13.305	13 1/4	2.090	2 1/16	21	2 7/8	1 1/8
×250[a]	73.5	26.34	26 3/8	1.040	1 1/16	9/16	13.185	13 1/8	1.890	1 7/8	21	2 11/16	1 1/8
×229	67.2	26.02	26	0.960	1	1/2	13.110	13 1/8	1.730	1 3/4	21	2 1/2	1
×207	60.7	25.71	25 3/4	0.870	7/8	7/16	13.010	13	1.570	1 9/16	21	2 3/8	1
×192	56.3	25.47	25 1/2	0.810	13/16	7/16	12.950	13	1.460	1 7/16	21	2 1/4	1
×176	51.7	25.24	25 1/4	0.750	3/4	3/8	12.890	12 7/8	1.340	1 5/16	21	2 1/8	15/16
×162	47.7	25.00	25	0.705	11/16	3/8	12.955	13	1.220	1 1/4	21	2	1 1/16
×146	43.0	24.74	24 3/4	0.650	5/8	5/16	12.900	12 7/8	1.090	1 1/16	21	1 7/8	1 1/16
×131	38.5	24.48	24 1/2	0.605	5/8	5/16	12.855	12 7/8	0.960	15/16	21	1 3/4	1 1/16
×117	34.4	24.26	24 1/4	0.550	9/16	5/16	12.800	12 3/4	0.850	7/8	21	1 5/8	1
×104	30.6	24.06	24	0.500	1/2	1/4	12.750	12 3/4	0.750	3/4	21	1 1/2	1
W 24×103[b]	30.3	24.53	24 1/2	0.550	9/16	5/16	9.000	9	0.980	1	21	1 3/4	13/16
× 94	27.7	24.31	24 1/4	0.515	1/2	1/4	9.065	9 1/8	0.875	7/8	21	1 5/8	1
× 84	24.7	24.10	24 1/8	0.470	1/2	1/4	9.020	9	0.770	3/4	21	1 9/16	15/16
× 76	22.4	23.92	23 7/8	0.440	7/16	1/4	8.990	9	0.680	11/16	21	1 7/16	15/16
× 68	20.1	23.73	23 3/4	0.415	7/16	1/4	8.965	9	0.585	9/16	21	1 3/8	15/16
W 24× 62	18.2	23.74	23 3/4	0.430	7/16	1/4	7.040	7	0.590	9/16	21	1 3/8	15/16
× 55	16.2	23.57	23 5/8	0.395	3/8	3/16	7.005	7	0.505	1/2	21	1 5/16	15/16

ANNEXURE-2 (Contd.)

W SHAPES
Properties



Nominal Wt. per Ft	Compact Section Criteria				r_T	$\frac{d}{A_f}$	Elastic Properties						Plastic Modulus		Designation
	$\frac{b_f}{2t_f}$	F_y'	$\frac{d}{t_w}$	F_y'''			Axis X-X			Axis Y-Y			Z_x	Z_y	
							I	S	r	I	S	r			
Lb.		Ksi		Ksi	In.		In.^{4}	In.^{3}	In.	In.^{4}	In.^{3}	In.	In.^{3}	In.^{3}	
492	2.0	—	15.1	—	3.80	0.59	19100	1290	11.5	1670	237	3.41	1550	375	W 24×492[a]
450	2.1	—	16.1	—	3.76	0.64	17100	1170	11.4	1490	214	3.36	1410	337	×450[a]
408	2.3	—	17.3	—	3.71	0.69	15100	1060	11.3	1320	191	3.33	1250	300	×408[a]
370	2.5	—	18.4	—	3.67	0.75	13400	957	11.1	1160	170	3.28	1120	267	×370[a]
335	2.7	—	19.9	—	3.63	0.82	11900	864	11.0	1030	152	3.23	1020	238	×335[a]
306	2.9	—	21.5	—	3.60	0.89	10700	789	10.9	919	137	3.20	922	214	×306[a]
279	3.2	—	23.0	—	3.57	0.96	9600	718	10.8	823	124	3.17	835	193	×279[a]
250	3.5	—	25.3	—	3.53	1.06	8490	644	10.7	724	110	3.14	744	171	×250[a]
229	3.8	—	27.1	—	3.51	1.15	7650	588	10.7	651	99.4	3.11	676	154	×229
207	4.1	—	29.6	—	3.48	1.26	6820	531	10.6	578	88.8	3.08	606	137	×207
192	4.4	—	31.4	—	3.46	1.35	6260	491	10.5	530	81.8	3.07	559	126	×192
176	4.8	—	33.7	58.2	3.44	1.46	5680	450	10.5	479	74.3	3.04	511	115	×176
162	5.3	—	35.5	52.5	3.45	1.58	5170	414	10.4	443	68.4	3.05	468	105	×162
146	5.9	—	38.1	45.6	3.43	1.76	4580	371	10.3	391	60.5	3.01	418	93.2	×146
131	6.7	—	40.5	40.3	3.40	1.98	4020	329	10.2	340	53.0	2.97	370	81.5	×131
117	7.5	—	44.1	33.9	3.37	2.23	3540	291	10.1	297	46.5	2.94	327	71.4	×117
104	8.5	58.5	48.1	28.5	3.35	2.52	3100	258	10.1	259	40.7	2.91	289	62.4	×104
103	4.6	—	44.6	33.2	2.33	2.78	3000	245	9.96	119	26.5	1.99	280	41.5	W 24×103[b]
94	5.2	—	47.2	29.6	2.33	3.06	2700	222	9.87	109	24.0	1.98	254	37.5	× 94
84	5.9	—	51.3	25.1	2.31	3.47	2370	196	9.79	94.4	20.9	1.95	224	32.6	× 84
76	6.6	—	54.4	22.3	2.29	3.91	2100	176	9.69	82.5	18.4	1.92	200	28.6	× 76
68	7.7	—	57.2	20.2	2.26	4.52	1830	154	9.55	70.4	15.7	1.87	177	24.5	× 68
62	6.0	—	55.2	21.7	1.71	5.72	1550	131	9.23	34.5	9.80	1.38	153	15.7	W 24× 62
55	6.9	—	59.7	18.5	1.68	6.66	1350	114	9.11	29.1	8.30	1.34	134	13.3	× 55

ANNEXURE-3

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

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

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

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

ANNEXURE-4

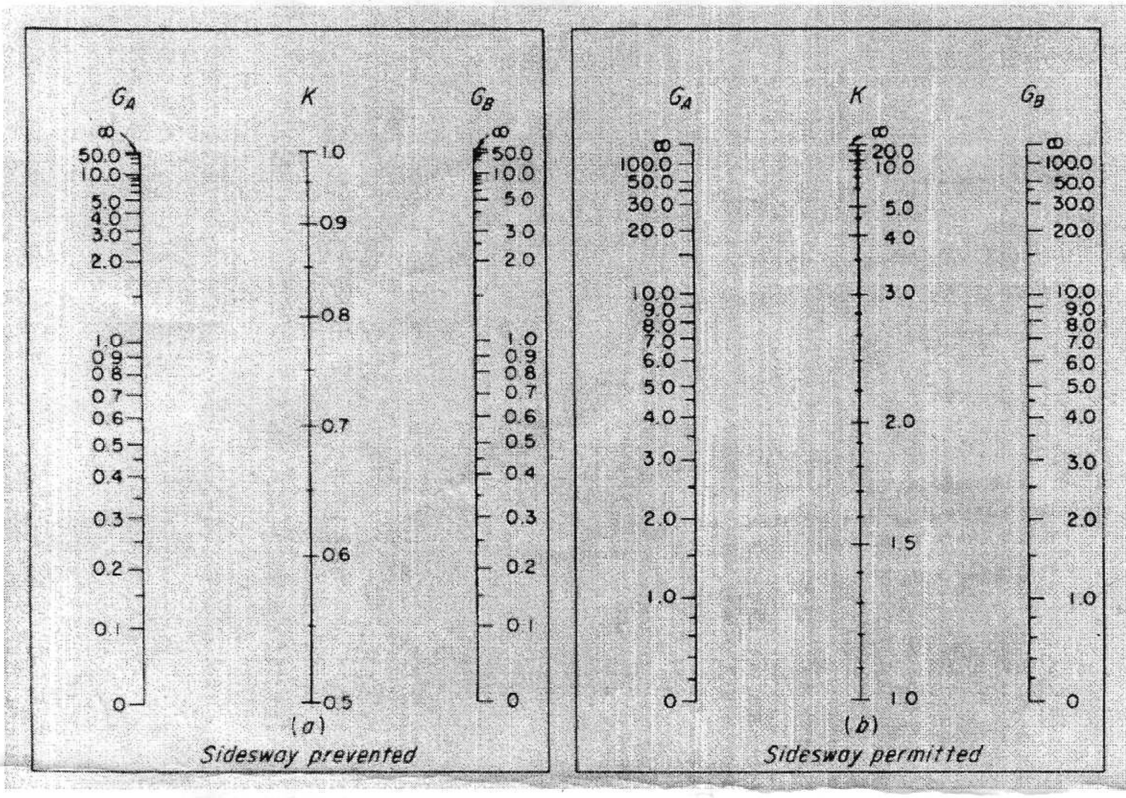
The AISC/LRFD design strength of columns is $\phi_c P_n$, where $\phi_c = 0.85$ and $P_n = A_g F_{cr}$, with F_{cr} given by

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

in which

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

ANNEXURE-5



Nomograph for effective length of columns.