Allowable Loads on Beams without Lateral Support

JOHN MATAYA

BEAMS WITH UNBRACED lengths along the compression flange greater than L_c or L_u require the designer to consider factors other than section modulus alone, since torsional properties and the lateral bending strength of the compression flange influence the ability of the beam to resist lateral buckling.

This paper presents tables developed to aid the designer in rapidly selecting the most economical W or I section for laterally unsupported beams.

NOMENCLATURE

A_f = Area of compression flange, sq in.
A_w = Area of web of steel section, sq in.
b_f = Flange width, in.
C = Constant determined from beam properties
C_b = Bending coefficient dependent upon moment gradient
= 1 for simple bending
= 1.75 for cantilever ends
= $1.75 - 1.05(M_1/M_2) + 0.3(M_1/M_2)^2 \leqq 2.3$ for beams or beam segments with moments at the points of lateral support
d = Depth of steel section, in.
F_b = Allowable bending stress, ksi
f_b = Computed bending stress, ksi
F_y = Specified minimum yield point of steel being used, ksi
I_f = Moment of inertia of the compression flange, in.^{4}. Use $\frac{1}{2}$ of the I_y values given in the AISC Manual.
I_y = Moment of inertia about the y-axis
l = Unbraced length, in.
L = Unsupported span length, ft
L_c = Maximum unbraced length of the compression flange at which the allowable bending stress may be taken at 0.66 F_y, ft
L_u = Maximum unbraced length of the compression flange at which the allowable bending stress may be taken at 0.60 F_y, ft
M = Moment, ft-kips
M_1 = Smaller end moment on unbraced length of beam, ft-kips
M_2 = Larger end moment on unbraced length of beam, ft-kips
r' = Radius of gyration of the tee section, comprising the compression flange plus $\frac{1}{6}$ of the web area, about an axis in the plane of the web, in.
= $\sqrt{I_f/(A_f + \frac{1}{6}A_w)}$
R = Reaction, kips
S = Section modulus, in.^{3}

John Mataya is Principal, Mataya, J. & Associates, Architects-Engineers, Chicago, Ill.

SPECIFICATION REQUIREMENTS

The AISC Specification permits an allowable bending stress, F_b, of 24 ksi for compact sections of ASTM A36 steel when the unbraced length along the compression flange is equal to or less than L_c. $L_c = (13/12)b_f$.

The Specification limits the allowable bending stress, F_b, for both compact and non-compact sections of A36 steel to 22 ksi when the unbraced length along the compression flange is greater than L_c, but equal to or less than L_u. $L_u = (545/12) \times d/A_f$ and $L_c < L \leqq L_u$.

When the unbraced length of the compression flange is greater than L_u the allowable bending stress, F_b, must be reduced in accordance with the provisions of Section 1.5.1.4.5 of the Specification, and may not exceed the larger value as given by the following Formulas, nor 0.60 F_y. For A36 steel,

$$F_b = 22{,}000 - \frac{0.672}{C_b}\left(\frac{l}{r'}\right)^2 \leqq (0.60F_y = 22 \text{ ksi}) \qquad \text{Formula (4)}$$

$$F_b = \frac{12{,}000{,}000}{L \times d/Af} \leqq 22 \text{ ksi} \qquad \text{Formula (5)}$$

An inspection of the allowable moment charts on pages **2**-48 to **2**-53 of the AISC Manual reveals that Formula (5) governs the allowable stress in most instances when I and WF shapes are used and the unbraced length exceeds L_u. In most cases where Formula (4) would govern, the decrease in allowable moments by the use of Formula (5) would be small. In every case the results would be conservative.

MATHEMATICAL DERIVATION

From Formula (5):

$$f_b = \frac{M}{S} = \frac{12{,}000{,}000}{L \times d/A_f}$$

$$\frac{M \times L}{12{,}000{,}000} = \frac{S}{d/A_f}$$

Let $$C = \frac{S}{d/A_f}$$

Then, $$C = \frac{12M \times L}{1{,}000} \qquad \text{Equation (1)}$$

TABLE PREPARATION

Tabular listings of C, S, L_c, L_u, d/A_f and r' are shown in Table 1 for all WF and I shapes listed in the AISC Manual of Steel Construction, 6th Edition, pages **1**-6 through **1**-25, as well as the six new light beam sections now being rolled by Bethlehem Steel Corp. and U. S. Steel Corp. Shapes are listed in the order of descending C-values to aid in selecting the most economical section.

The r' values were determined using $I_f = \frac{1}{2}I_y$ in the formula given in the Nomenclature.

USE OF TABLE 1

Example 1—Select the most economical simple beam to support a uniform load of 2 kips/lin ft over a span of 20 ft. Lateral bracing is provided at the supports. Use A36 steel. See Fig. 1.

Solution:

$$F_b = 22 \text{ ksi}$$

$$R = 2 \times \frac{20}{2} = 20 \text{ kips}$$

$$M = 2 \times \frac{20}{8} = 100 \text{ ft-kips}$$

$$\text{Req'd } S = 100 \times \frac{12}{22} = 54.5 \text{ in.}^3$$

$$\text{Req'd minimum } C = \frac{12 \times M \times L}{1{,}000} =$$

$$\frac{12 \times 100 \times 20}{1{,}000} = 24.0 \qquad \text{Equation (1)}$$

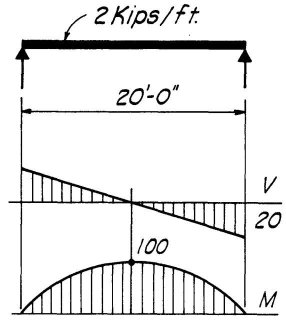

Figure 1

1. The minimum required C as computed by Equation (1) is 24.0. Therefore, select from Table 1 the lightest steel section with C equal to or greater than the computed C and with S equal to or greater than the required S, 54.5 in.³.

   From Table 1:

C	Shape	S	L_c	L_u	d/A_f	r'	Remarks
25.7	18WF55	98.2	8.2	11.9	3.82	1.90	OK
24.4	18I70	101.9	6.8	10.9	4.17	1.40	OK
24.2	14WF48	70.2	8.7	15.7	2.90	2.16	**USE**
24.1	10WF45	49.1	8.7	22.3	2.04	2.20	NG

2. The 10WF45 is inadequate, because the furnished S of 49.1 is less than the 54.5 in.³ required if the beam was fully braced at intervals equal to or less than L_u.
3. From Formula (4), $F_b = 22{,}000 - 0.679/C_b(l/r')^2$, and by inspection of the table the least amount of reduction in F_b occurs when the r' value is the largest. Therefore; the 14WF48 ($r' = 2.16$) would be the most economical and least weight section.
4. For normal cases, calculations need go no further. For illustrative purposes, however, compute F_b by Formulas (4) and (5) for the 14WF48 with $S = 70.2$, $r' = 2.16$, $d/A_f = 2.90$.

$$F_b = 22{,}000 - \frac{0.679}{1}\left(\frac{20 \times 12}{2.16}\right)^2 = 13.62 \text{ ksi}$$

Formula (4)

$$F_b = \frac{12{,}000{,}000}{20 \times 12 \times 2.90} = 17.24 \text{ ksi (governs)}$$

Formula (5)

5. The permitted allowable stress is 17.24 ksi (the largest of the values computed by Formulas (4) and (5)).

$$f_{\text{actual}} = \frac{100 \times 12}{70.2} = 17.1 < 17.24 \qquad \textbf{OK}$$

6. The designer should check for shear as well as architectural considerations.

TABLE 1 (A36 steel)

C	Shape	S	L_c	L_u	d/A_f	r'
1916.6	14WF426	707.4	18.1	123.1	0.329	4.65
1693.0	14WF398	656.9	18.0	117.1	0.388	4.62
1484.3	14WF370	608.1	17.9	110.8	0.410	4.58
1286.0	14WF342	559.4	17.7	104.4	0.435	4.55
1103.2	14WF314	511.9	17.6	97.9	0.464	4.51
1024.5	14WF320	492.8	18.1	94.4	0.481	4.58
934.7	14WF287	465.5	17.5	91.2	0.498	4.48
843.6	36WF300	1105.1	18.0	34.7	1.31	4.29
804.9	14WF264	427.4	17.4	85.5	0.531	4.45
736.6	36WF280	1031.2	18.0	32.5	1.40	4.27
707.1	14WF246	397.4	17.3	80.8	0.562	4.43
659.0	14WF237	382.2	17.2	78.3	0.580	4.42
625.7	36WF260	951.1	17.9	29.9	1.52	4.23
616.1	14WF228	367.8	17.2	76.1	0.597	4.41
570.6	14WF219	352.6	17.1	73.5	0.618	4.39
550.9	36WF245	892.5	17.9	28.1	1.62	4.20
537.2	33WF240	811.1	17.2	30.1	1.51	4.07
531.7	14WF211	339.2	17.1	71.2	0.638	4.38
492.3	14WF202	324.9	17.1	68.8	0.660	4.37
482.9	36WF230	835.5	17.8	26.3	1.73	4.17
451.9	14WF193	310.0	17.0	66.2	0.686	4.36
448.8	33WF220	740.6	17.1	27.5	1.65	4.03
424.8	30WF210	649.9	16.4	29.7	1.53	3.89
414.9	14WF184	295.8	17.0	63.7	0.713	4.35
402.4	12WF190	263.2	13.7	69.4	0.654	3.51
379.4	14WF176	281.9	16.9	61.1	0.743	4.34
367.9	33WF200	669.6	17.1	25.0	1.82	3.99
346.8	30WF190	586.1	16.3	26.9	1.69	3.85
344.0	14WF167	267.3	16.9	58.5	0.777	4.33
312.1	14WF158	253.4	16.8	55.9	0.812	4.32
302.3	27WF177	492.8	15.3	27.9	1.63	3.62
297.9	12WF161	222.2	13.6	60.9	0.746	3.47
282.5	30WF172	528.2	16.2	24.3	1.87	3.81
282.3	14WF150	240.2	16.8	53.4	0.850	4.30
277.7	36WF194	663.6	13.1	19.0	2.39	3.01
266.8	24WF160	413.5	15.3	29.3	1.55	3.65
253.3	14WF142	226.7	16.2	50.7	0.895	4.29
246.9	27WF160	444.5	15.2	25.3	1.80	3.59
243.6	36WF182	621.2	13.1	17.8	2.55	3.00
229.5	14WF136	216.0	16.0	48.3	0.941	4.08
217.8	24WF145	372.5	15.2	26.6	1.71	3.62
212.9	21WF142	317.2	14.2	30.5	1.49	3.42
212.1	36WF170	579.1	13.0	16.7	2.73	2.97
208.6	12WF133	183.5	13.4	51.9	0.875	3.42
204.5	27WF145	402.9	15.1	23.1	1.97	3.55
202.6	14WF127	202.0	15.9	45.6	0.997	4.07
184.0	36WF160	541.0	13.0	15.5	2.94	2.94
178.7	14WF119	189.4	15.9	42.9	1.06	4.06
177.5	33WF152	486.4	12.5	16.6	2.74	2.88
172.2	21WF127	284.1	14.1	27.5	1.65	3.39
171.3	24WF130	330.7	15.2	23.6	1.93	3.57
169.7	12WF120	163.4	13.3	47.2	0.963	3.40
157.6	36WF150	502.9	13.0	14.2	3.19	2.91
156.0	14WF111	176.3	15.8	40.2	1.13	4.05
148.4	33WF141	446.8	12.5	15.1	3.01	2.84
145.0	*14BP117	172.6	16.1	42.7	1.19	4.03
144.2	10WF112	126.3	11.3	51.8	0.876	2.89
139.3	18WF114	220.1	12.8	28.8	1.58	3.09
138.5	24WF120	299.1	13.1	21.0	2.16	3.09
136.3	*14WF103	163.6	15.8	41.6	1.20	4.03
135.1	12WF106	144.5	13.3	42.4	1.07	3.38
133.5	21WF112	249.6	14.1	24.3	1.87	3.35
132.3	30WF132	379.7	11.4	15.8	2.87	2.62
120.5	33WF130	404.8	12.5	13.5	3.36	2.80
118.2	18WF105	202.2	12.8	26.6	1.71	3.07
118.2	12WF99	134.7	13.2	39.8	1.14	3.37
117.3	24WF110	274.4	13.0	19.4	2.34	3.06
117.0	36WF135	438.6	—	12.1	3.75	2.84
117.0	10WF100	112.4	11.2	47.3	0.961	2.87
115.8	*14WF95	150.6	15.8	38.6	1.30	4.02
115.1	30WF124	354.6	11.4	14.8	3.08	2.60
111.4	*14BP102	150.4	16.0	37.0	1.35	4.00
103.3	12WF92	125.0	13.2	37.5	1.21	3.35
102.8	27WF114	299.2	10.9	15.6	2.91	2.52
102.5	16WF96	166.1	12.5	28.1	1.62	3.02
99.1	18WF96	184.4	12.8	24.4	1.86	3.04
98.6	*14WF87	138.1	15.7	35.6	1.40	4.01
97.6	30WF116	327.9	11.4	13.5	3.36	2.57
96.5	24WF100	248.9	13.0	17.6	2.58	3.03
94.1	10WF89	99.7	11.1	42.8	1.06	2.84
92.6	24I120	250.9	8.7	16.8	2.71	1.90
92.3	33WF118	358.3	—	11.7	3.88	2.74
89.7	12WF85	115.7	13.1	35.2	1.29	3.34
86.1	14WF84	130.9	13.0	29.9	1.52	3.31
85.8	*14BP89	131.2	15.9	32.6	1.53	3.97
85.5	16WF88	151.3	12.5	25.7	1.77	3.00
84.9	24I105.9	234.3	8.5	16.5	2.76	1.90
81.4	27WF102	266.3	10.9	13.9	3.27	2.49
80.0	30WF108	299.2	11.4	12.2	3.74	2.42
79.0	21WF96	197.6	9.8	18.2	2.50	2.30
77.1	12WF79	107.1	13.1	32.7	1.39	3.33
74.3	14WF78	121.1	13.0	27.9	1.63	3.30
72.0	24WF94	220.9	9.8	14.8	3.07	2.28
71.8	10WF77	86.1	11.0	37.8	1.20	2.82
68.5	18WF85	156.1	9.6	19.9	2.28	2.29
67.3	27WF94	242.8	10.8	12.6	3.61	2.46
64.1	*12WF72	97.5	13.0	32.9	1.52	3.32
63.6	30WF99	269.1	—	10.7	4.23	2.48
62.6	10WF72	80.1	11.0	35.5	1.28	2.81
62.4	14WF74	112.3	10.9	25.3	1.80	2.75
58.9	16WF78	127.8	9.3	20.9	2.17	2.23
58.1	*14BP73	107.5	15.8	27.0	1.85	3.94
57.4	*12BP74	93.5	13.2	30.6	1.63	3.29
57.3	21WF82	168.0	9.7	15.5	2.93	2.27
56.9	18WF77	141.7	9.5	18.3	2.49	2.27
56.6	24WF84	196.3	9.8	13.1	3.47	2.25
53.8	10WF66	73.7	11.0	33.2	1.37	2.80
52.8	20I95	160.0	7.8	15.0	3.03	1.67

* *Non-compact section*

TABLE 1 (A36 steel)

C	Shape	S	L_c	L_u	d/A_f	r'
52.8	14WF68	103.0	10.9	23.3	1.95	2.74
52.7	*12WF65	88.0	13.0	30.0	1.67	3.31
52.1	8WF67	60.4	9.0	39.2	1.16	2.29
51.9	24I100	197.6	7.9	11.9	3.81	1.63
50.3	27WF84	211.7	10.8	10.8	4.21	2.40
48.7	16WF61	115.9	9.3	19.1	2.38	2.21
48.6	20I85	150.2	7.6	14.7	3.09	1.67
48.0	24I90	185.8	7.7	11.7	3.87	1.63
46.8	18WF70	128.2	9.5	16.6	2.74	2.25
45.0	24WF76	175.4	9.7	11.7	3.90	2.22
45.0	10WF60	67.1	10.9	30.5	1.49	2.79
44.1	24I79.9	173.9	7.6	11.5	3.94	1.64
43.6	21WF73	150.7	9.0	13.1	3.46	2.08
42.7	14WF61	92.2	10.8	21.0	2.16	2.72
41.1	12WF58	78.1	10.8	23.9	1.90	2.76
39.6	16WF64	104.2	9.2	17.3	2.63	2.19
39.4	8WF58	52.0	8.9	34.4	1.32	2.27
39.1	18WF64	117.0	9.4	15.2	2.99	2.23
37.5	21WF68	139.9	9.0	12.2	3.73	2.07
37.1	10WF54	60.4	10.9	27.9	1.63	2.78
33.9	*10BP57	58.9	11.1	28.8	1.74	2.76
33.8	12WF53	70.7	10.8	21.7	2.09	2.74
33.7	24WF68	153.1	9.7	10.0	4.55	2.17
32.3	16WF58	94.1	9.2	15.6	2.91	2.17
31.8	20I75	126.3	6.9	11.4	3.97	1.47
31.0	18WF60	107.8	8.2	13.1	3.48	1.91
30.5	21WF62	126.4	8.9	11.0	4.15	2.04
30.5	*10WF49	54.6	10.8	28.0	1.79	2.76
29.9	*12BP53	67.0	13.1	22.3	2.24	3.25
29.6	14WF53	77.8	8.7	17.3	2.63	2.17
28.9	20I65.4	116.9	6.8	11.2	4.05	1.47
28.2	8WF48	43.2	8.8	29.7	1.53	2.25
27.5	12WF50	64.7	8.8	19.3	2.53	2.20
25.7	18WF55	98.2	8.2	11.9	3.82	1.90
24.4	18I70	101.9	6.8	10.9	4.17	1.40
24.2	14WF48	70.2	8.7	15.7	2.90	2.16
24.1	10WF45	49.1	8.7	22.3	2.04	2.20
22.7	24WF61	129.5	7.6	8.0	5.71	1.72
22.6	21WF55	109.7	8.9	9.4	4.85	2.00
22.4	12WF45	58.2	8.7	17.5	2.60	2.18
22.1	16WF50	80.7	7.7	12.4	3.66	1.80
21.1	18WF50	89.0	8.1	10.8	4.22	1.88
20.3	18I54.7	88.4	6.5	10.4	4.35	1.40
19.4	14WF43	62.7	8.7	14.0	3.24	2.15
19.4	8WF40	35.5	8.8	24.8	1.83	2.23
18.8	*10BP42	43.4	10.9	21.7	2.31	2.72
18.0	12WF40	51.9	8.7	15.7	2.89	2.17
17.9	10WF39	42.2	8.7	19.3	2.36	2.19
17.8	16WF45	72.4	7.6	11.2	4.07	1.78
17.0	24WF55	113.7	—	6.8	6.69	1.69
16.5	18WF45	78.9	8.1	9.5	4.79	1.85
15.5	21WF49	93.2	—	7.6	6.00	1.62
15.2	8WF35	31.1	8.7	22.2	2.05	2.21
15.2	12I50	50.3	5.9	13.7	3.32	1.29
15.0	15I50	64.2	6.1	10.6	4.28	1.30
14.2	16WF40	64.4	7.6	10.0	4.54	1.76
13.5	*8BP36	29.9	8.8	22.6	2.21	2.20
13.4	15I42.9	58.9	6.0	10.4	4.39	1.29
13.4	14WF38	54.6	7.3	11.2	4.06	1.72
13.3	12WF36	45.9	7.1	13.2	3.45	1.70
13.3	8M34.3	28.9	8.7	20.8	2.18	2.07
12.9	12I40.8	44.8	5.7	13.1	3.47	1.27
12.8	8M32.6	28.2	8.6	20.6	2.20	2.06
12.4	*10WF33	35.0	8.6	17.7	2.83	2.17
12.0	18WF40	68.3	6.5	8.0	5.68	1.53
11.9	*8WF31	27.4	8.7	21.6	2.31	2.20
11.6	21WF44	81.5	—	6.4	7.05	1.59
10.6	16WF36	56.3	7.6	8.6	5.30	1.72
10.6	14WF34	48.5	7.3	9.9	4.58	1.70
9.9	12WF31	39.4	7.1	11.4	3.98	1.68
9.14	8WF28	24.3	7.1	17.1	2.66	1.79
8.75	10WF29	30.8	6.3	12.9	3.52	1.51
8.71	12I35	37.8	5.5	10.5	4.34	1.19
8.42	18WF35	57.9	6.5	6.6	6.88	1.50
8.16	12I31.8	36.0	5.4	10.3	4.41	1.19
7.78	14WF30	41.8	7.3	8.5	5.37	1.66
7.48	6M25	15.7	6.4	21.6	2.10	1.55
7.45	8M28	22.5	7.2	15.1	3.02	1.69
7.41	12WF27	34.1	7.0	9.9	4.60	1.65
7.30	6WF25	16.8	6.6	19.7	2.30	1.67
7.24	16B31	47.0	6.0	7.0	6.49	1.36
7.09	10I35	29.2	5.4	11.0	4.12	1.13
6.80	8M24	21.0	7.0	14.7	3.09	1.69
6.78	8WF24	20.8	7.0	14.8	3.07	1.79
6.47	10WF25	26.4	6.2	11.1	4.08	1.49
6.21	10M29.1	26.6	6.4	10.6	4.28	1.38
5.58	10I25.4	24.4	5.0	10.4	4.37	1.12
5.34	10M22.9	23.6	6.2	10.3	4.42	1.38
5.28	14B26	34.9	5.4	6.9	6.61	1.25
5.27	6M22.5	13.7	6.6	17.5	2.60	1.52
4.85	6M20	12.9	6.4	17.1	2.66	1.52
4.77	6WF20	13.4	6.5	16.2	2.81	1.65
4.62	16B26	38.0	—	5.5	8.25	1.31
4.24	10WF21	21.5	6.2	9.0	5.07	1.44
4.17	8WF20	17.0	5.7	11.1	4.08	1.36
4.15	10M21	21.1	6.2	9.2	5.09	1.41
4.09	5WF18.5	9.94	5.4	18.7	2.43	1.39
4.06	8M22.5	17.1	5.8	10.8	4.21	1.76
3.96	5WF18.9	9.5	5.4	18.9	2.40	1.31
3.58	8M18.5	15.5	5.7	10.5	4.33	1.27
3.55	8I23	16.0	4.5	10.1	4.51	0.978
3.52	14B22	28.8	5.4	5.6	8.19	1.21
3.51	12B22	25.3	4.4	6.3	7.20	1.02
3.11	8M20	15.2	5.8	9.3	4.89	1.27
3.07	5WF16	8.53	5.4	16.3	2.78	1.38
3.01	8I18.4	14.2	4.3	9.7	4.71	0.969
2.91	10B19	18.8	4.4	7.0	6.47	1.03
2.85	8WF17	14.1	5.7	9.2	4.95	1.33

* *Non-compact section*

TABLE 1 (A36 steel)

C	Shape	S	L_c	L_u	d/A_f	r'
2.80	8M17	14.0	5.7	9.1	5.00	1.27
2.72	*6WF15.5	10.1	6.5	13.5	3.72	1.63
2.63	6B16	10.1	4.4	11.8	3.84	1.08
2.60	7I20	12.0	4.2	9.8	4.62	0.885
2.46	12B19	21.4	4.3	5.2	8.69	0.994
2.13	7I15.3	10.4	4.0	9.3	4.88	0.893
2.11	10B17	16.2	4.3	5.9	7.67	1.01
1.90	4M13	5.2	4.2	16.6	2.73	1.03
1.86	6I17.25	8.7	3.9	9.7	4.69	0.825
1.84	4WF13	5.45	4.4	15.3	2.97	1.10
1.83	8B15	11.8	4.3	7.1	6.44	1.03
1.63	14B17.2	21.0	—	3.5	12.9	0.922
1.56	12B16.5	17.5	—	4.1	11.2	0.959
1.49	10B15	13.8	4.3	4.9	9.29	0.985
1.45	6I12.5	7.3	3.6	9.1	5.02	0.802
1.35	6B12	7.24	4.3	8.4	5.38	1.04

C	Shape	S	L_c	L_u	d/A_f	r'
1.29	5I14.75	6.0	3.6	9.7	4.67	0.771
1.26	8B13	9.88	4.3	5.8	7.87	1.00
1.11	12B14	14.8	—	3.4	13.4	0.941
0.939	5I10	4.8	3.3	8.9	5.11	0.729
0.854	*10B11.5	10.5	—	4.1	12.3	0.960
0.792	*8B10	7.79	—	5.1	9.83	1.00
0.690	12JR11.8	12.0	—	2.6	17.4	0.691
0.675	4I9.5	3.3	3.0	9.3	4.89	0.673
0.664	*6B8.5	5.07	—	6.6	7.63	0.321
0.585	4I7.7	3.0	2.9	8.9	5.13	0.659
0.431	10JR9.0	7.8	—	2.5	18.1	0.617
0.413	3I7.5	1.9	2.7	9.9	4.60	0.609
0.343	3I5.7	1.7	2.5	9.2	4.95	0.583
0.253	8JR6.5	4.7	—	2.4	18.6	0.531
0.187	7JR5.5	3.5	2.3	2.4	18.7	0.493
0.126	6JR4.4	2.4	2.0	2.4	19.0	0.448

* *Non-compact section*

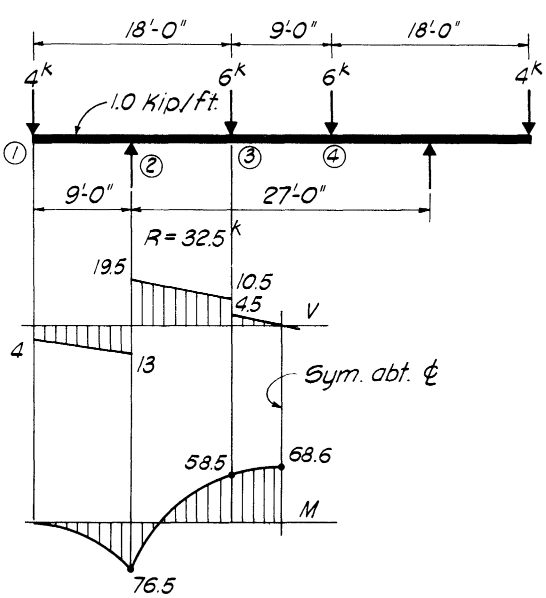

Figure 2

Example 2—Select the most economical beam for the span and load condition illustrated in Fig. 2. Lateral supports are provided at 9-ft intervals between the supports and continuous for the free ends. Use A36 steel.

Solution:

The points of application of load and points of vertical support are also points of support against lateral buckling. The critical buckling section is the region of high positive moment between points of lateral support (3) and (4), and the maximum positive moment should be used to determine the required value of C.

From Equation (1),

$$C = \frac{12 \times 68.6 \times 9}{1{,}000} = 7.41$$

The points of maximum negative moment are critical sections as far as maximum allowable stress ($F_b = 0.60F_y$) is concerned; therefore, maximum negative moment should be used to determine the required S.

$$\text{Req'd } S = 76.5 \times \frac{12}{22} = 41.7 \text{ in.}^3$$

1. The minimum required C as computed by Equation (1) is 7.41. The minimum required S is 41.7 in.^{3}. Select from Table 1 sections with C-values equal to or greater than the required C, having values of S equal to or greater than the required S, until the most economical section is determined.

From Table 1:

C	Shape	S	L_c	L_u	d/A_f	r'	Remarks
8.71	12I35	37.8	5.5	10.5	4.34	1.19	NG
8.42	18WF35	57.9	6.5	6.6	6.88	1.50	OK
8.16	12I31.8	36.0	5.4	10.3	4.41	1.19	NG
7.78	14WF30	41.8	7.3	8.5	5.37	1.66	**USE**
7.48	6M25	15.7	6.4	21.6	2.10	1.55	NG
7.45	8M28	22.5	7.2	15.1	3.02	1.69	NG
7.41	12WF27	34.1	7.0	9.9	4.60	1.65	NG

Select the 14WF30 as the lightest section having the required C and S values.

2. For normal cases, calculations need go no further. However, for illustrative purposes, check the 14W30 with $S = 41.8$, $r' = 1.66$, $d/A_f = 5.37$.

$$C_{b\ 1-2} = 1.75 \text{ for cantilever ends}$$

$$C_{b\ 2-3} = 1.75 - 1.05\left(-\frac{58.5}{76.5}\right) + 0.3\left(-\frac{58.5}{76.5}\right)^2$$

$$= 2.82 \text{ (use 2.3)}$$

$$C_{b\ 3-4} = 1$$

Formula (4):

$$F_{b\ 1-2} = 22{,}000 - \frac{0.679}{1.75}\left(\frac{9 \times 12}{1.66}\right)^2 = 20.36 \text{ ksi}$$

$$F_{b\ 2-3} = 22{,}000 - \frac{0.679}{2.3}\left(\frac{9 \times 12}{1.66}\right)^2 = 20.75 \text{ ksi}$$

$$F_{b\ 3-4} = 22{,}000 - \frac{0.679}{1}\left(\frac{9 \times 12}{1.66}\right)^2 = 19.12 \text{ ksi}$$

Formula (5):

$$F_b = \frac{12{,}000{,}000}{9 \times 12 \times 5.37} = 20.7 \text{ ksi}$$

3. The permitted allowable stress is 20.7 ksi, the largest of the values computed by Formulas (4) and (5).

$$f_{\text{actual}} = \frac{68.6 \times 12}{41.8} = 19.7 < 22.0 \text{ ksi} \qquad \textbf{OK}$$

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