LRFD Aid for Tubeshaped Beams

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In a previous issue of the *Engineering Journal*,[1] the first author presented beam design aids in the form of an "economic section" table for laterally supported standard tubeshaped beams designed according to the 1978 AISC Specifications.[2] The authors feel that with the increasing use of the 1986 AISC LRFD Specifications,[3] a table similar in scope and content but using the LRFD specifications would be highly desirable. The accompanying tables would greatly facilitate the selection of tubular flexural members and would complement the existing beam design aids available for other rolled shapes in the LRFD manual.[4]

The design aid information available here is valid for tubular sections used as beams. It is assumed that the loading is applied in the plane of the minor axis and that the beam deflects vertically in the plane of bending only. This paper uses the same nomenclature as the LRFD manual.

LATERAL SUPPORT AND WIDTH-THICKNESS RATIO REQUIREMENTS

The LRFD Specifications define limiting width-thickness ratios (λ) and their limits λ_p, λ_r for flange-buckling (FLB) and web-buckling (WLB) in Section B5 Table B5.1 in the LRFD Specifications.[3] If $\lambda \leq \lambda_r$ for both FLB and WLB, then the section is compact. If $\lambda_p < \lambda \leq \lambda_r$ then the section is noncompact. Shapes with $\lambda > \lambda_r$ are said to have slender compression elements. In computing the *b/t* ratios, *b* was taken to be the full width minus three times the wall thickness. Of the 180 tube shapes listed in the LRFD manual, only two: TS 16×16×5/16 and TS 12×12×¼ fall in the category of having slender compression elements for both F_y = 46 ksi and 50 ksi; TS 14×14×5/16 is slender for F_y = 50 ksi. The moment capacities of shapes with slender compression elements are not included in these tables. However, using the precedent set in the new LRFD manual, noncompact shapes are included in these tables.

Lateral support requirements for compact shapes can be best defined in terms of the limits L_p and L_r. L_p is defined as the limiting laterally unbraced length for inelastic lateral torsional buckling (or LTB). L_r is the corresponding unbraced limit for elastic LTB. If the unbraced length, L_b is less than L_p, the maximum design resisting moment of a section is given by $\phi_b M_p$, provided the shape satisfies compact section requirements; when $L_b = L_r$ the moment capacity is $\phi_b M_r$. For compact sections with $L_p < L_b \leq L_r$, the moment capacity varies linearly between M_p *and* M_r and can be computed using the tabulated values and a factor *BF* with the formula

$$\phi_b M_n = C_b[\phi_b M_p - BF(L_b - L_p)] \leq \phi_b M_p$$

For compact shapes M_p and M_r are defined by $\phi_b M_p = \phi_b Z_x F_y/12$ and $\phi_b M_r = \phi_b S_x(F_y - F_r)/12$. A value of 16.5 ksi was used for F_r. In the absence of explicit guidelines for tube shapes in the Specifications or in the Commentary, the authors feel it is prudent to use this value. One should also note that although Section F1.1 in the LRFD Specifications[3] states that there is no limit on L_b for members with square cross sections, nonetheless values for L_p computed using LRFD Specification Formula F1-5[3] are provided for square tubes.

For noncompact shapes, the maximum flexural design strength $\phi_b M_n'$ has been computed using Formula A-F1-3 of the LRFD Specifications[3] and is tabulated as $\phi_b M_p$. The associated maximum unbraced length, L_p', is computed using

$$L_p' = L_p + (L_r - L_p)(M_p - M_n')/(M_p - M_r)$$

and is tabulated as L_p. In the tables, values of L_p larger than 99 ft for the noncompact shapes are not shown; *BF* is also excluded in these cases since for most practical design cases L_b for these shapes used as beams will not exceed 99 ft, however, the value of $\phi_b M_r$ is shown just for the sake of completeness. M_r is computed in the same manner as for compact shapes.

The user should note that unlike the LRFD manual, no values for L_r are provided in the table. This is because the shapes listed in this table have very large values for L_r with the smallest value being 78 ft for a TS 12×2×¼ of F_y = 50 ksi.

USE OF TABLES

Example 1

Select a beam of F_y = 46 ksi subjected to a factored uniform bending moment of 186 kip-ft, having its compression flange braced at 6.0 ft intervals (C_b = 1.0).

Solution

$$Z_x(\text{reqd.}) = M_u(12)/\phi_b F_y = 186(12)/0.9(46) = 53.91 \text{ in}^3$$

Entering the tables, it is found that the nearest higher tabulated value of Z_x is 54.20 in^3, which corresponds to a TS 10×6×5/8 weighing 59.32 lb/ft. Proceeding up that specific group of shapes, the first shape represented in boldface is

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TS 16×4×5/16 weighing 40.35 lb/ft with $Z_x = 54.50$ in^3. It represents the most economic tubular shape. Noting that $L_p = 7.8$ ft > 6.0 ft, the capacity $\phi_b M_n = \phi_b M_p = 188$ k-ft is more than the required strength of 186 kip-ft, the shape is adequate.

Use TS 16×4×5/16 $\phi_b M_n$ = 188 kip-ft.

Example 2

Determine the moment capacity of a TS 16×4×3/8 of F_y = 50 ksi with the compression flange braced at 9.0 ft. intervals. Use $C_b = 1.0$.

Solution

Entering the tables for $F_y = 50$ ksi one notes that for the TS 16×4×3/8, $\phi_b M_p = 240.7$ kip-ft, $L_p = 7.0$ ft, $BF = 0.588$ kips. Since $L_b > 7.0$ ft, the capacity is given by

$$\phi_b M_n = C_b[\phi_b M_p - BF\,(L_b - L_p)] \leq \phi_b M_p$$
$$= 1.0[240.7 - 0.588(9 - 7)] = 239 \text{ kip ft}$$

For F_y = 50 ksi, TS 16×4×3/8 (L_b = 9.0 ft)
$\phi_b M_n$ = 239 kip-ft

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LOAD FACTOR DESIGN SELECTION TABLE FOR TUBE SHAPES
$\phi_b = 0.9$

F_y = 46 ksi							F_y = 50 ksi			
BF Kips	Lp Ft	$\phi_b M_r$ Kip-ft	$\phi_b M_p$ Kip-ft	Z_x in^3	Shape	Wt lb/ft	$\phi_b M_p$ Kip-ft	$\phi_b M_r$ Kip-ft	Lp Ft	BF Kips
0.313	**37.6**	**365.1**	**693.5**	**201.0**	**20x12x1/2**	**103.3**	**753.8**	**414.6**	**34.6**	**0.368**
0.174	89.4	331.9	598.4	175.0	16x16x1/2†	103.30	642.2	376.9	#	-
0.460	**20.7**	**281.0**	**558.9**	**162.0**	**20x 8x1/2**	**89.68**	**607.5**	**319.1**	**19.0**	**0.543**
0.237	**61.6**	**283.2**	**525.7**	**154.0**	**20x12x3/8†**	**78.52**	**562.9**	**321.6**	**87.3**	**0.278**
0.207	40.6	265.5	496.8	144.0	16x12x1/2	89.68	540.0	301 5	37 4	0 243
-	#	256.7	416.5	134.0	16x16x3/8†	78.52	441.9	291.5	#	-
0.150	51.2	250.0	455.4	132.0	14x14x1/2	89 68	495.0	283.9	47 1	0 176
-	**#**	**239.0**	**413.0**	**130.0**	**20x12x5/16†**	**65.87**	**438.1**	**271.4**	**#**	**-**
0.351	20.9	218.6	431.3	125.0	20x8x3/8	68.31	468.8	248.2	19.2	0 414
1.153	6 2	196.7	424.4	123.0	20x4x1/2	76.07	461.3	223.4	5.7	1 370
0.506	13.8	201 1	410.6	119.0	18x6x1/2	76.07	446.3	228.4	12.7	0 598
0.289	23.0	199.6	389.9	113.0	16x8x1/2	76.07	423 8	226.6	21.1	0.340
0.159	64.5	206.9	379.2	111.0	16x12x3/8†	68 31	406.4	234.9	90.2	0.186
0.291	**21.2**	**185.4**	**362.3**	**105.0**	**20x 8x5/16**	**57.36**	**393.8**	**210.5**	**19.5**	**0.343**
0 185	33.3	192.3	362.3	105.0	14x10x1/2	76.07	393.8	218.3	30.6	0.217
-	#	194.5	332.5	102.0	14x14x3/8†	68.31	354.8	220.8	#	-
0.127	43 8	179 0	329.1	95.40	12x12x1/2	76.07	357 8	203.3	40.3	0 149
0.854	6.5	154 7	328.8	95.30	20x4x3/8	58 10	357.4	175.6	6 0	1 013
-	#	175.7	300.4	93 80	16x12x5/16†	57.36	319.4	199.5	#	-
0 385	14.1	157.8	318 1	92.20	18x6x3/8	58.10	345.8	179.1	12 9	0 455
0.221	23 2	156.2	302.2	87.60	16x8 x3/8	58 10	328 5	177.4	21 4	0 260
0 201	25 41	54 2	300.5	87.10	12x 8x5/8	76 33	326 6	175 1	23 4	0 237
-	#	165.1	262.4	86 10	14x14x5/16~	57 36	-	-	-	-
0.658	7.3	133 2	283 6	82.20	16x4x1/2	62 46	308 3	151 3	6 7	0 781
0.143	33.4	150.5	281.2	81 50	14x10x3/8	58 10	305 6	170 9	30 7	0 167
0.711	**6.6 1**	**31.9**	**278.8**	**80.80**	**20x4x5/16**	**48.86**	**303.0**	**149.7**	**6.1**	**0.843**
0.292	15.8	134.5	270.1	78.30	14x6x1/2	62.46	293.6	152 8	14.5	0.345
0 323	14.2	134.3	269.4	78.10	18x6x5/16	48 86	292.9	152.5	13.1	0 381
0.126	36.0	142.0	267.7	77.60	10x10x5/8	76.33	291.0	161.3	33.1	0 148
0.186	23.4	133.0	256.0	74.20	16x8x5/16	48.86	278 3	151.0	21.5	0.219
0.098	67.0	140.3	252.7	73.90	12x12x3/8†	58.10	271.2	159.3	91.7	0.115
0.257	16.7	124.3	251.5	72.90	12x6x5/8	67.82	273.4	141.2	15.3	0.303

F_y = 46 ksi							F_y = 50 ksi			
BF Kips	Lp Ft	$\phi_b M_r$ Kip-ft	$\phi_b M_p$ Kip-ft	Z_x in^3	Shape	Wt lb/ft	$\phi_b M_p$ Kip-ft	$\phi_b M_r$ Kip-ft	Lp Ft	BF Kips
0.165	25.8	130.3	249.8	72.40	12x 8x1/2	62.46	271.5	148.0	23 7	0.194
0.120	53.4	128.1	235.7	69.00	14x10x5/16†	48.86	252.5	145.5	75.0	0.141
0.475	8.0	105.8	223.6	64.80	14x 4x1/2	55.66	243.0	120.1	7.3	0.564
0.104	36.3	119.9	222.9	64.60	10x10x1/2	62.46	242.3	136.2	33.4	0.122
0.496	**7.6**	**105.8**	**221.5**	**64.20**	**16x4x3/8**	**47.90**	**240.7**	**120.1**	**7.0**	**0.588**
-	#	119.5	202.1	62.60	12x12x5/16†	48.86	215.4	135.7	#	-
0.223	16.1	106.4	210.8	61.10	14x6x3/8	47.90	229.1	120.9	14.8	0.263
0.211	17.0	105.8	210.1	60.90	12x6x1/2	55.66	228.4	120.1	15.6	0.249
0.127	26.0	102.9	194.9	56.50	12x8x3/8	47.90	211.9	116.8	23.9	0.150
0.411	**7.8**	**90.5**	**188.0**	**54 50**	**16x4x5/16**	**40.35**	**204.4**	**102.8**	**7.1**	**0.487**
0.176	8.0	93.4	187.0	54.20	10x6x5/8	59.32	203.3	106.0	16.6	0.208
0.188	16.2	91.2	179.1	51.90	14x6x5/16	40.35	194.6	103.5	14 9	0.222
0.359	8.3	84.5	175.3	50 80	14x4x3/8	42.79	190.5	96.0	7.6	0.425
0 081	36.5	94.9	173.9	50.40	10x10x3/8	47 90	189.0	107 8	33 5	0 094
0.330	8 8	81.4	170.4	49.40	12x4x1/2	48.85	185.3	92.5	8.1	0.391
0.107	26 1	88 1	165 3	47.90	12x8x5/16	40.35	179.6	100 0	24.0	0 126
0 162	17 3	84 3	164 6	47.70	12x6x3/8	42.79	178.9	95 7	15.9	0.191
0.097	28.5	84.7	162 8	47.20	8x8x5/8	59.32	177 0	96.2	26.3	0.114
0.146	18.3	80.1	157.3	45.60	10x6x1/2	48.85	171.0	91.0	16.9	0 172
0.301	**8.4**	**72.6**	**149.4**	**43.30**	**14x4x5/16**	**36.10**	**162.4**	**82.4**	**7.8**	**0.356**
0.068	55.8	81.2	146.3	42.80	10x10x5/16†	40.35	157 1	92.2	76.6	0 080
0.153	**16.3**	**74.8**	**145.9**	**42.30**	**14x6x1/4**	**32.63**	**158.6**	**84.9**	**15.0**	**0.180**
0.137	17 4	72.1	140.1	40.60	12x6x5/16	36.10	152.3	81.9	16.0	0 161
0.080	29.0	72.8	137.0	39 70	8x8x1/2	48.85	148.9	82.7	26.7	0 094
0.087	42 2	72.1	133.5	39.10	12x8x1/4†	32.63	143.0	81.9	59 6	0 103
0.251	9.1	65.5	134 6	39.00	12x4x3/8	37 69	146.3	74.4	8.4	0.298
0.216	9 8	60.0	124.5	36.10	10x4x1/2	42.05	135.4	68.1	9.0	0.256
0 113	18.6	64.2	123.9	35.90	10x6x3/8	37.69	134.6	72 9	17.1	0.133
0.243	**8.5**	**59.7**	**122.1**	**35.40**	**14x4x1/4**	**29.23**	**132.8**	**67.8**	**7.9**	**0.287**
-	#	66.6	111.0	34.90	10x10x1/4†	32.63	118.1	75.6	#	-
0 211	9.2	56.4	114.9	33.30	12x4x5/16	31.84	124.9	64.1	8.5	0 250
0.112	17.4	59 5	114 5	33.20	12x6x1/4	29.23	124.5	67.6	16.0	0.131

F_y = 46 ksi							F_y = 50 ksi			
BF Kips	Lp Ft	$\phi_b M_r$ Kip-ft	$\phi_b M_p$ Kip-ft	Z_x in^3	Shape	Wt lb/ft	$\phi_b M_p$ Kip-ft	$\phi_b M_r$ Kip-ft	Lp Ft	BF Kips
0.095	19.9	57.1	111.1	32.20	8x6x1/2	42.05	120.8	64.8	18.3	0.112
0.063	29.1	58.4	108.0	31.30	8x8x3/8	37.69	117.4	66.3	26.8	0.074
0.096	18.7	55.3	105.9	30.70	10x6x5/16	31.84	115.1	62.8	17.2	0.113
0.069	25.1	53.5	102.1	29.60	7x7x1/2	42.05	111.0	60.8	23.1	0.081
0.168	10.0	48.7	99.0	28.70	10x4x3/8	32.58	107.6	55 3	9.2	0.199
0.171	**9.3**	**46.7**	**94.2**	**27.30**	**12x4x1/4**	**25.82**	**102.4**	**53.0**	**8.6**	**0.202**
0.053	29.2	50.2	92.1	26.70	8x8x5/16	31.84	100.1	57.0	26.9	0.062
0.075	20.1	46.2	88.3	25.60	8x6x3/8	32.58	96.0	52.5	18.4	0.088
0.085	**29.5**	**45.8**	**86.6**	**25.40**	**12x 6x3/16†**	**22.18**	**92.6**	**52.0**	**42.6**	**0.100**
0.078	18.8	45.6	86.6	25.10	10x6x1/4	25.82	94.1	51.8	17.3	0.092
0.132	10.9	41.6	85.2	24.70	8x4x1/2	35.24	92.6	47.2	10.1	0.157
0.142	10.2	2.3	84.9	24.60	10x4x5/16	27.59	92.3	48.0	9.4	0.167
0.054	25.4	43.4	81.1	23.50	7x7x3/8	32.58	88.1	49.2	23.3	0.064
0.084	16.1	40.0	79.7	23.10	7x5x1/2	35.24	86.6	45.5	14.8	0.099
0.044	44.5	41.6	74.9	21.90	8x8x1/4†	25.82	80.4	47.2	61.0	0.051
0.064	20.2	40.0	75.6	21.90	8x6x5/16	27.59	82.1	45.5	18.6	0.075
0.443	2.8	33.4	74.2	21.50	10x2x3/8	27.48	80.6	37.9	2.6	0.528
0.462	2.7	34.1	73.8	21.40	12x2x1/4	22.42	80.3	38.7	2.5	0.549
0.130	**9.5**	**36.3**	**72.5**	**21.00**	**12x4x3/16**	**19.63**	**78.8**	**41.2**	**8.7**	**0.153**
0.057	21.4	37.2	72.1	20.90	6x6x1/2	35.24	78.4	42.2	19.7	0.067
0.114	10.4	35.2	69.7	20.20	10x4x1/4	22.42	75.8	39.9	9.5	0.135
0.046	25.5	37.6	69.3	20.10	7x7x5/16	27.59	75.4	42.7	23.5	0.054
0.104	11.2	34.3	68.7	19.90	8x4x3/8	27.48	74.6	38.9	10.3	0.123
0.060	30.7	35.4	65.9	19.30	10x6x3/16†	19.63	70.5	40.2	43.7	0.070
0.362	3.0	29.2	63.8	18.50	10x2x5/16	23.34	69.4	33.2	2.7	0.430
0.067	16.3	33.0	63.8	18.50	7x5x3/8	27.48	69.4	37.4	15.0	0.078
0.052	20.3	33.2	62.1	18.00	8x6x1/4	22.42	67.5	37.7	18.7	0.061
0.089	11.3	29.9	59.0	17.10	8x4x5/16	23.34	64.1	33.9	10.4	0.104
0.141	7.0	28.1	58.7	17.00	8x3x3/8	24.93	63.8	31.9	6.5	0.167
-	#	32.3	52.4	16.80	8x8x3/16†	19.63	55.6	36.7	#	-
0.046	21.6	30.8	58.0	16.80	6x6x3/8	27.48	63.0	34.9	19 9	0.053
0.343	**2.8**	**26.6**	**57.3**	**16.60**	**12x2x3/16**	**17.08**	**62.3**	**30.2**	**2.6**	**0.407**
0.038	25.6	31.2	56.9	16.50	7x7x1/4	22.42	61.9	35.4	23.6	0.044
0.079	11.9	27.9	55.2	16.00	7x4x3/8	24.93	60.0	31.7	10.9	0.093
0.057	16.5	28.8	54.9	15.90	7x5x5/16	23.34	59.6	32.7	15.2	0 066
0.087	10.5	27.2	53.8	15.60	10x4x3/16	17.08	58.5	30.9	9.7	0.103
0.289	3.1	24.6	53.1	15.40	10x2x1/4	19.02	57.8	27.9	2 8	0.344
0 074	12.2	26.1	53.1	15.40	6x4x1/2	28.43	57.8	29.6	11.3	0.087
0.119	7.2	24.8	50.7	14.70	8x3x5/16	21.21	55.1	28.1	6.6	0 141
0.039	21.8	26.8	49.7	14.40	6x6x5/16	23.34	54.0	30.4	20 1	0.045
0.248	3.3	22.1	9.0	14.20	8x2x3/8	22.37	53 3	25.1	3.0	0 296
0 072	11.5	25.0	48.6	14.10	8x4x1/4	19.02	52.9	28.4	10.6	0.085
0.040	32.2	25.9	47.5	13.90	8x6x3/16†	17.08	50.9	29.4	45.1	0.047
0.067	12.0	24.3	47.6	13.80	7x4x5/16	21.21	51.8	27.6	11.1	0 079
0.046	17 7	23 9	47.3	13.70	5x5x1/2	28.43	51.4	27.1	16.2	0.054
0.104	7.6	22.6	46.6	13.50	7x3x3/8	22.37	50.6	25.6	7.0	0.123
0.047	16.5	24.1	45.5	13.20	7x5x1/4	19.02	49.5	27.4	15.2	0.055
-	#	24.3	41.5	12.70	7x7x3/16†	17.08	44.3	27.6	#	-
0.058	12.6	21.9	43.1	12 50	6x4x3/8	22.37	46.9	24.9	11 6	0 069
0 205	3.5	19.6	42.4	12.30	8x2x5/16	19 08	46.1	22.3	3.2	0 244
0 097	7.4	20.8	42.1	12.20	8x3x1/4	17.32	45.8	23 6	6 8	0 115
0.032	21.9	22.3	41.1	11.90	6x6x1/4	19.02	44.6	25 4	20 1	0 037
0.216	**3.2**	**19.3**	**41.1**	**11.90**	**10x2x3/16**	**14.53**	**44.6**	**22.0**	**3.0**	**0.256**
0.090	7.7	19 9	40 7	11.80	7x3x5/16	19.08	44.3	22.6	7 1	0 107
0.056	12.1	20.4	39.7	11.50	7x4x1/4	17.32	43 1	23 2	11.2	0 065
0.037	17.9	20.2	38.6	11.20	5x5x3/8	22.37	42.0	22.9	16.5	0.043
0.056	11.6	19.5	38.0	11 00	8x4x3/16	14.53	41.3	22.2	10.6	0.066

F_y = 46 ksi							F_y = 50 ksi			
BF Kips	Lp Ft	$\phi_b M_r$ Kip-ft	$\phi_b M_p$ Kip-ft	Z_x in^3	Shape	Wt lb/ft	$\phi_b M_p$ Kip-ft	$\phi_b M_r$ Kip-ft	Lp Ft	BF Kips
0 050	12.7	19.3	37.6	10.90	6x4x5/16	19.08	40.9	21.9	11.7	0.059
0.074	8.2	17.5	35.9	10.40	6x3x3/8	19.82	39.0	19.9	7.6	0.087
0.167	3.6	16.6	35.5	10.30	8x2x1/4	15.62	38.6	18.9	3.3	0.199
0.036	16.7	18.8	35.2	10.20	7x5x3/16	14.53	38.3	21.4	15.3	0.042
0.073	7.9	16.8	33.8	9.79	7x3x1/4	15.62	36.7	19.1	7.2	0.086
0.032	18.0	17.7	33.5	9.70	5x5x5/16	19.08	36.4	20.2	16.6	0.037
0.075	**7.5**	**16.4**	**32.7**	**9.49**	**8x3x3/16**	**13.25**	**35.6**	**18.6**	**6.9**	**0.088**
0.041	13.4	6.6	32.6	9.44	5x4x3/8	19.82	35.4	18.8	12.3	0.049
0.025	33.5	17.5	31.6	9.24	6x6x3/16†	14.53	33.9	19.9	45.8	0.029
0.063	8.5	14.9	31.7	9.20	5x3x1/2	21.63	34.5	17.0	7.8	0.075
0.064	8.3	15.6	31.4	9.11	6x3x5/16	16.96	34.2	17.7	7.6	0.076
0.041	12.9	16.3	31.3	9.06	6x4x1/4	15.62	34.0	18.5	11.8	0.049
0.043	12.3	16.1	30.7	8.91	7x4x3/16	3.25	33.4	18.2	11.3	0.050
0.120	4.0	13.1	28.7	8.33	6x2x3/8	17.27	31.2	14.9	3.7	0.143
0.036	13.5	14.7	28.4	8.24	5x4x5/16	16.96	30.9	16.7	12.4	0.042
0.026	18.1	15.0	27.8	8.07	5x5x1/4	15.62	30.3	17.0	16.7	0.031
0.034	13.9	13.6	27.7	8.02	4x4x1/2	21.63	30.1	15.4	12.8	0.040
0.125	**3.8**	**13.2**	**27.7**	**8.02**	**8x2x3/16**	**11.97**	**30.1**	**15.0**	**3.5**	**0.148**
0.051	8.9	13.0	26.6	7.71	5x3x3/8	17.27	28.9	14.8	8.2	0.060
0.056	8.0	13.3	26.3	7.63	7x3x3/16	11.97	28.6	15.1	7.4	0.066
0.053	8.5	13.2	26.3	7.62	6x3x1/4	13.91	28.6	15.0	7.8	0.062
0.102	4.2	11.8	25.3	7.33	6x2x5/16	14.83	27.5	13.4	3.9	0.121
0.032	13.0	12.9	24.4	7.06	6x4x3/16	11.97	26.5	14.6	2.0	0.037
0.030	13.6	12.5	23.8	6.89	5x4x1/4	13.91	25.8	14.2	12.5	0.035
0.044	9.0	11.7	23.4	6.77	5x3x5/16	14.83	25.4	13.2	8.3	0.052
0.028	14.2	11.8	23.2	6.72	4x4x3/8	17.27	25.2	13.4	13.0	0.033
0.020	18.2	11.9	21.7	6.29	5x5x3/16	11.97	23.6	13.5	16.8	0.024
0.083	4.4	10.2	21.3	6.18	6x2x1/4	12.21	23.2	11.6	4.0	0.098
0.041	**8.6**	**10.5**	**20.6**	**5.97**	**6x3x3/16**	**10.70**	**22.4**	**12.0**	**7.9**	**0.048**
0.024	4.3	10.6	20.4	5.90	4x4x5/16	14.83	22.1	12.0	13.1	0.029
0.036	9.2	10.0	19.7	5.70	5x3x1/4	12.21	21.4	11.4	8.5	0.043
0.023	13.7	9.9	18.6	5.39	5x4x3/16	10.70	20.2	11.3	12.6	0.027
0.066	4.7	8.6	18.3	5.31	5x2x5/16	12.70	19.9	9.8	4.3	0.078
0.020	14.4	9.1	17.1	4.97	4x4x1/4	12.21	18.6	10.3	13.2	0.024
0.064	**4.5**	**8.2**	**16.8**	**4.88**	**6x2x3/16**	**9.42**	**18.3**	**9.3**	**4.1**	**0.076**
0.029	9.7	8.2	16.4	4.75	4x3x5/16	12.70	17.8	9.3	9.0	0.034
0.055	4.8	7.5	15.6	4.51	5x2x1/4	10.51	16.9	8.5	4.4	0.065
0.028	9.2	8.0	15.5	4.49	5x3x3/16	9.42	16.8	9.1	8.5	0.034
0.021	12.5	7.7	15.0	4.35	3x3.5x5/16	12.70	16.3	8.7	11.5	0.024
0.024	9.9	7.1	13.9	4.03	4x3x1/4	10.51	15.1	8.1	9.1	0.028
0.016	14.5	7.3	13.5	3.91	4x4x3/16	9.42	14.7	8.3	13.3	0.018
0.017	12.6	6.7	12.8	3.70	3.5x3.5x1/4	10.51	13.9	7.6	11.6	0.020
0.040	5.3	5.9	12.4	3.60	4x2x5/16	10.58	13.5	6.7	4.8	0.047
0.042	**5.0**	**6.1**	**12.4**	**3.59**	**5x2x3/16**	**8.15**	**13.5**	**6.9**	**4.6**	**0.050**
0.019	10.0	5.8	11.0	3.20	4x3x3/16	8.15	12.0	6.6	9.2	0.022
0.033	5.5	5.2	10.7	3.09	4x2x1/4	8.81	11.6	5.9	5.0	0.039
0.017	10.5	5.3	10.5	3.04	3x3x5/16	10.58	11.4	6.0	9.7	0.020
0.013	12.7	5.4	10.1	2.93	3.5x3.5x3/16	8.15	11.0	6.2	11.7	0.016
0.014	10.7	4.6	9.0	2.61	3x3x1/4	8.81	9.8	5.3	9.8	0.017
0.026	**5.6**	**4.3**	**8.6**	**2.48**	**4x2x3/16**	**6.87**	**9.3**	**4.8**	**5.1**	**0.031**
0.011	10.7	3.8	7.2	2.10	3x3x3/16	6.87	7.9	4.3	9.9	0.013
0.018	6.1	3.3	6.6	1.92	3x 2x1/4	7.11	7.2	3.7	5.6	0.022
0.011	8.7	3.0	5.9	1.71	2.5x 2.5x1/4	7.11	6.4	3.4	8.0	0.014
0.015	**6.3**	**2.7**	**5.4**	**1.57**	**3x2x3/16**	**5.59**	**5.9**	**3.1**	**5.8**	**0.017**
0.009	8.9	2.5	4.8	1.40	2.5x 2.5x3/16	5.59	5.3	2.9	8.2	0.011
0.009	**6.9**	**1.7**	**3.5**	**1.00**	**2x 2x1/4**	**5.41**	**3.8**	**1.9**	**6.3**	**0.010**
0.007	**7.0**	**1.5**	**2.9**	**0.84**	**2x2x3/16**	**4.32**	**3.2**	**1.7**	**6.5**	**0.008**

† Indicates noncompact shape, F_y = 46 ksi and F_y = 50 ksi

~ Indicates noncompact shape, F_y = 46 ksi and slender F_y = 50 ksi

# Indicates L_p > 100 ft.