

LRFD Beam Tables for Structural Tubes

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In his practice, the author often uses structural tubes as flexural members in areas that will be visible in the completed structure. Tubes, being closed sections, have excellent resistance to lateral-torsional buckling and are more visually pleasing than W-shapes.

An allowable stress design aid for structural tubes used as beams has been previously published in this Journal.¹ As this author is shifting his practice from allowable stress design to LRFD, load factor design selection tables were developed in accordance with the LRFD Specification.² These tables are set up similar to the beam selection tables in Part 3 of the LRFD Manual of Steel Construction.³ Only compact sections are listed in the table.

The governing design equation is:

$$\phi_b M_n = C_b [\phi_b M_p - BF(L_b - L_p)] \leq \phi_b M_p \quad (1)$$

where:

$$M_p = F_y Z_x$$

$$\phi_b = 0.90$$

$$L_p = \text{limiting laterally unbraced length for full plastic bending capacity LTB, ft. } C_b = 1.0$$

$$= 3750 r_y \sqrt{J A / M_p} \quad (\text{F1-5})$$

$$L_r = \text{limiting laterally unbraced length for elastic LTB, feet.}$$

$$= 57000 r_y \sqrt{J A / M_r} \quad (\text{F1-10})$$

$$M_r = F_y S_{eff} = \text{effective section modulus about major axis, in.} \quad (\text{F1-11})$$

$$BF = \text{a factor that can be used to calculate the design moment capacity for unbraced lengths } L_b, \text{ between } L_p \text{ and } L_r, \text{ kips.}$$

$$= \phi_b (M_p - M_r) / (L_r - L_p)$$

The use of the equation F1-11 for calculating M_r was approved in October 1989 by the AISC Specification Committee. This, in effect, assigns a value of 0 ksi to residual stress in structural tubes. Prior to this, the LRFD Specification was silent as to the proper residual stress for structural tube design.

The table has been developed for yield strengths of 46 ksi

and 50 ksi. The values of L_r are omitted since the least value is in excess of 75 ft and the greatest is in excess of 1000 ft. It would be impossible to exceed the value of L_r in any actual design. Likewise, the value of M_r is also omitted.

An asterisk (*) is placed after M_p for sections which may become non-compact in the presence of axial load, in accordance with section B5 of the LRFD specification. If axial load is present, compactness should be checked for these sections.

Example 1

Select a structural steel tube for an unbraced length of 14 ft and $\phi_b M_n = 65.0$ kip-ft. $F_y = 46$ ksi. $C_b = 1.0$.

Solution: TS 12×4×3/16

$$BF = 0.091$$

$$L_p = 9.49 \text{ ft}$$

$$\phi_b M_p = 72.45 \text{ kip-ft}$$

$$\phi_b M_n = 1.0[72.45 - 0.091(14.00 - 9.49)] = 72.04 \text{ kip-ft} \geq 65.0 \text{ kip-ft} \quad \text{OK} \quad (1)$$

Use TS 12×4×3/16.

Example 2

Select a structural steel tube for an unbraced length of 8 ft and $\phi_b M_n = 20.0$ kip-ft. $F_y = 46$ ksi. $C_b = 1.0$.

Solution: TS 6×3×3/16

$$L_p = 8.63 \text{ ft } L_p \geq L_b$$

$$\phi_b M_p = 20.60 \text{ kip-ft} \geq 20.0 \text{ kip-ft} \quad \text{OK}$$

Use TS 6×3×3/16.

REFERENCES

1. Siddiqui, Faruq M. A., "A Beam Design Aid for Structural Tubing," *Engineering Journal*, Volume 23, No. 4, 4th Quarter, 1986.
2. American Institute of Steel Construction, "Load and Resistance Factor Design Specification for Structural Steel Buildings," Chicago, IL, 1986.
3. American Institute of Steel Construction, *LRFD Manual of Steel Construction*, First Edition, Chicago, IL, 1986.

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Table 1.
LRFD Moment Capacities of Structural Tubing

F _y = 46 ksi										F _y = 50 ksi									
BF	L	M _p	SHAPE	WEIGHT	Z _x	M _p	L	BF		BF	L	M _p	SHAPE	WEIGHT	Z _x	M _p	L	BF	
kips	ft	f-k				f-k	ft	kips		kips	ft	f-k				f-k	ft	kips	
0.236	37.33	845.25	TS 20 X 12 X 5/8	127.37	245.00	918.75	34.34	0.279		0.074	11.62	68.31	TS 7 X 4 X 1/2	31.84	19.80	74.25	10.69	0.087	
0.112	58.26	738.30	TS 16 X 16 X 5/8	127.37	214.00	802.50	53.60	0.133		0.047	15.10	66.58	TS 9 X 5 X 1/4	22.42	19.30	72.37	13.90	0.056	
0.188	37.62	693.45	TS 20 X 12 X 1/2	103.30	201.00	753.75*	34.61	0.223		0.043	16.31	63.82	TS 7 X 5 X 3/8	27.48	18.50	69.37	15.00	0.050	
0.148	40.36	603.75	TS 16 X 12 X 5/8	110.36	175.00	656.25	37.13	0.175		0.302	2.98	63.82	TS 10 X 2 X 5/16	23.34	18.50	69.37	2.74	0.357	
0.318	20.68	558.90	TS 20 X 8 X 1/2	89.68	162.00	607.50*	19.02	0.375		0.043	16.85	62.44	TS 6 X 5 X 1/2	31.84	18.10	67.87	15.50	0.050	
0.100	50.92	555.45	TS 14 X 14 X 5/8	110.36	161.00	603.75	46.85	0.118		0.030	20.29	62.10	TS 8 X 6 X 1/4	22.42	18.00	67.50	18.67	0.035	
0.118	40.64	496.80	TS 16 X 12 X 1/2	89.68	144.00	540.00	37.39	0.140		0.118	6.71	62.10	TS 9 X 3 X 5/16	23.34	18.00	67.50	6.18	0.140	
0.076	51.23	455.40	TS 14 X 14 X 1/2	89.68	132.00	495.00	47.14	0.090		0.043	14.63	60.03*	TS 10 X 5 X 3/16	18.35	17.40	65.25*	13.46	0.051	
0.237	20.89	431.25*	TS 20 X 8 X 3/8	68.31	125.00	468.75*	19.22	0.280		0.060	11.33	58.99	TS 8 X 4 X 5/16	23.34	17.10	64.12	10.43	0.071	
0.945	6.21	424.35	TS 20 X 4 X 1/2	76.07	123.00	461.25	5.72	1.117		0.109	7.04	58.65	TS 8 X 3 X 3/8	24.93	17.00	63.75	6.48	0.129	
0.372	13.79	410.55	TS 18 X 6 X 1/2	76.07	119.00	446.25	12.68	0.440		0.027	21.60	57.96	TS 6 X 6 X 3/8	27.48	16.80	63.00	19.87	0.032	
0.089	43.30	400.20	TS 12 X 12 X 5/8	93.34	116.00	435.00	39.84	0.105		0.019	25.63	56.92	TS 7 X 7 X 1/4	22.42	16.50	61.87	23.58	0.023	
0.190	22.98	389.85	TS 16 X 8 X 1/2	76.07	113.00	423.75	21.14	0.224		0.054	11.88	55.20	TS 7 X 4 X 3/8	24.93	16.00	60.00	10.93	0.064	
0.191	21.17	362.25*	TS 20 X 8 X 5/16	57.36	105.00	393.75*	19.47	0.226		0.035	16.48	54.85	TS 7 X 5 X 5/16	23.34	15.90	59.62	15.16	0.041	
0.108	33.26	362.25	TS 14 X 10 X 1/2	76.07	105.00	393.75	30.60	0.128		0.100	16.27	145.93*	TS 14 X 6 X 1/4	32.63	42.30	158.62*	14.97	0.118	
0.068	43.78	329.13	TS 12 X 12 X 1/2	76.07	95.40	357.75	40.28	0.080		0.122	13.97	140.76	TS 10 X 5 X 1/2	45.45	40.80	153.00	12.85	0.144	
0.682	6.51	328.78*	TS 20 X 4 X 3/8	58.10	95.30	357.37*	5.99	0.806		0.088	17.40	140.97	TS 12 X 6 X 5/16	36.10	40.60	152.25	16.01	0.104	
0.275	14.05	318.09*	TS 18 X 6 X 3/8	58.10	92.20	345.75*	12.93	0.325		0.038	32.75	139.03	TS 9 X 9 X 3/8	42.79	40.30	151.12	30.13	0.045	
0.141	23.24	302.22*	TS 16 X 8 X 3/8	58.10	87.60	328.50*	21.38	0.167		0.047	28.98	136.96	TS 8 X 8 X 1/2	48.85	39.70	148.87	26.67	0.055	
0.131	25.42	300.49	TS 12 X 8 X 5/8	76.33	87.10	326.62	23.39	0.155		0.187	9.58	135.93	TS 10 X 4 X 9/16	46.51	39.40	147.75	8.81	0.221	
0.527	7.28	283.59	TS 16 X 4 X 1/2	62.46	82.20	308.25	6.70	0.623		0.188	9.09	134.55	TS 12 X 4 X 3/8	37.69	39.00	146.25	8.36	0.222	
0.081	33.40	281.17	TS 14 X 10 X 3/8	58.10	81.50	305.62	30.73	0.096		0.079	19.02	133.51	TS 9 X 6 X 1/2	45.45	38.70	145.12	17.50	0.094	
0.562	6.64	278.76	TS 20 X 4 X 5/16	48.86	80.80	303.00	6.11	0.664		0.109	14.49	129.72	TS 9 X 5 X 9/16	46.51	37.60	141.00	13.33	0.129	
0.116	25.59	275.65	TS 12 X 8 X 9/16	69.48	79.90	299.62	23.55	0.138		0.043	27.56	126.61	TS 10 X 8 X 5/16	36.10	36.70	137.62	25.36	0.051	
0.206	15.75	270.13	TS 14 X 6 X 1/2	62.46	78.30	293.62	14.49	0.244		0.165	9.76	124.54	TS 10 X 4 X 1/2	42.05	36.10	135.37	8.98	0.195	
0.228	14.21	269.44*	TS 18 X 6 X 5/16	48.86	78.10	292.87*	13.07	0.269		0.072	18.57	123.85	TS 10 X 6 X 3/8	37.69	35.90	134.62	17.09	0.085	
0.074	36.02	267.72	TS 10 X 10 X 5/8	76.33	77.60	291.00	33.14	0.087		0.179	8.54	122.13*	TS 14 X 4 X 1/4	29.23	35.40	132.75*	7.86	0.212	
0.117	23.38	255.99	TS 16 X 8 X 5/16	48.86	74.20	278.25	21.51	0.138		0.070	19.75	121.44	TS 8 X 6 X 9/16	46.51	35.20	132.00	18.17	0.083	
0.185	16.66	251.50	TS 12 X 6 X 5/8	67.82	72.90	273.37	15.33	0.218		0.097	14.62	118.68	TS 9 X 5 X 1/2	42.05	34.40	129.00	13.45	0.114	
0.102	25.79	249.78	TS 12 X 8 X 1/2	62.46	72.40	271.50	23.73	0.121		0.031	32.91	118.33	TS 9 X 9 X 5/16	36.10	34.30	128.62	30.28	0.037	
0.066	36.11	245.98	TS 10 X 10 X 9/16	69.48	71.30	267.37	33.22	0.078		0.049	23.75	116.61	TS 9 X 7 X 3/8	37.69	33.80	126.75	21.85	0.058	
0.165	16.77	231.49	TS 12 X 6 X 9/16	61.83	67.10	251.62	15.43	0.195		0.154	9.25	114.88	TS 12 X 4 X 5/16	31.84	33.30	124.87	8.51	0.182	
0.091	27.05	227.35	TS 10 X 8 X 5/8	67.82	65.90	247.12	24.88	0.107		0.070	17.43	114.54*	TS 12 X 6 X 1/4	29.23	33.20	124.50*	16.04	0.083	
0.376	7.96	223.56	TS 14 X 4 X 1/2	55.66	64.80	243.00	7.32	0.444		0.090	14.24	111.43	TS 10 X 5 X 3/8	35.13	32.30	121.12	13.10	0.107	
0.058	36.29	222.87	TS 10 X 10 X 1/2	62.46	64.60	242.25	33.39	0.068		0.048	25.02	111.43	TS 7 X 7 X 9/16	46.51	32.30	121.12	23.02	0.057	
0.385	7.57	221.49*	TS 16 X 4 X 3/8	47.90	64.20	240.75*	6.96	0.455		0.062	19.94	111.09	TS 8 X 6 X 1/2	42.05	32.20	120.75	18.34	0.073	
0.068	32.24	212.17	TS 9 X 9 X 5/8	67.82	61.50	230.62	29.66	0.080		0.034	29.13	107.98	TS 8 X 8 X 3/8	37.69	31.30	117.37	26.80	0.040	
0.153	16.06	210.79	TS 14 X 6 X 3/8	47.90	61.10	229.12	14.77	0.180		0.060	18.69	105.91	TS 10 X 6 X 5/16	31.84	30.70	115.12	17.20	0.070	
0.145	16.97	210.10	TS 12 X 6 X 1/2	55.66	60.90	228.37	15.61	0.171		0.058	19.27	105.57	TS 9 X 6 X 3/8	35.13	30.60	114.75	17.73	0.069	
0.081	27.13	209.07	TS 10 X 8 X 9/16	61.83	60.60	227.25	24.96	0.096		0.042	25.14	102.12	TS 7 X 7 X 1/2	42.05	29.60	111.00	23.13	0.050	
0.326	8.45	202.17	TS 12 X 4 X 5/8	59.32	58.60	219.75	7.77	0.385		0.040	23.91	99.36	TS 9 X 7 X 5/16	31.84	28.80	108.00	22.00	0.047	
0.060	32.43	195.27	TS 9 X 9 X 9/16	61.83	56.60	212.25	29.84	0.071		0.123	10.02	99.01	TS 10 X 4 X 3/8	32.58	28.70	107.62	9.22	0.145	
0.076	26.00	194.92	TS 12 X 8 X 3/8	47.90	56.50	211.87	23.92	0.090		0.074	14.40	95.22	TS 10 X 5 X 5/16	29.72	27.60	103.50	13.25	0.088	
0.072	27.25	190.09	TS 10 X 8 X 1/2	55.66	55.10	206.62	25.07	0.084		0.072	14.87	94.18	TS 9 X 5 X 3/8	32.58	27.30	102.37	13.68	0.085	
0.314	7.76	188.02*	TS 16 X 4 X 5/16	40.35	54.50	204.37*	7.14	0.371		0.113	9.35	94.18*	TS 12 X 4 X 1/4	25.82	27.30	102.37*	8.60	0.145	
0.291	8.61	186.99	TS 12 X 4 X 9/16	54.17	54.20	203.25	7.93	0.344		0.123	10.70	92.80	TS 8 X 4 X 9/16	38.86	26.90	100.87	9.84	0.134	
0.124	18.03	186.99	TS 10 X 6 X 5/8	59.32	54.20	203.25	16.59	0.146		0.028	29.25	92.11	TS 8 X 8 X 5/16	31.84	26.70	100.12	26.91	0.033	
0.126	16.18	179.05*	TS 14 X 6 X 5/16	40.35	51.90	194.62*	14.88	0.149		0.046	19.42	90.04	TS 9 X 6 X 5/16	29.72	2				

**Table 1 (continued).
LRFD Moment Capacities of Structural Tubing**

F _y = 46 ksi										F _y = 50 ksi									
BF	L _p	I _x	SHAPE	WEIGHT	Z _x	I _p	L _p	BF		BF	L _p	I _x	SHAPE	WEIGHT	Z _x	I _p	L _p	BF	
kips	ft	f-k		lb./ft	in ³	f-k	ft	kips		kips	ft	f-k		lb./ft	in ³	f-k	ft	kips	
0.035	15.30	51.06*	TS 9 X 5 X 3/16	17.08	14.80	55.50*	14.08	0.041		0.046	8.31	31.43	TS 6 X 3 X 5/16	16.96	9.11	34.16	7.64	0.055	
0.032	17.05	50.71	TS 6 X 5 X 3/8	24.93	14.70	55.12	15.69	0.038		0.026	12.85	31.26	TS 6 X 4 X 1/4	15.62	9.06	33.97	11.82	0.030	
0.088	7.22	50.71	TS 8 X 3 X 5/16	21.21	14.70	55.12	6.64	0.104											
0.021	21.81	49.68	TS 6 X 6 X 5/16	23.34	14.40	54.00	20.07	0.025		0.009	14.50	13.49	TS 4 X 4 X 3/16	9.42	3.91	14.66	13.34	0.010	
0.211	3.33	48.99	TS 8 X 2 X 3/8	22.37	14.20	53.25	3.07	0.250		0.011	12.56	12.76	TS 3½ X 3½ X 1/4	10.51	3.70	13.87	11.55	0.013	
0.047	11.51	48.64	TS 8 X 4 X 1/4	19.02	14.10	52.87	10.59	0.055		0.031	5.29	12.42	TS 4 X 2 X 5/16	10.58	3.60	13.50	4.87	0.037	
0.044	12.04	47.61	TS 7 X 4 X 5/16	21.21	13.80	51.75	11.08	0.052		0.031	5.01	12.39	TS 5 X 2 X 3/16	8.15	3.59	13.46	4.61	0.036	
0.031	17.66	47.26	TS 5 X 5 X 1/2	28.43	13.70	51.37	16.24	0.037		0.011	10.00	11.04	TS 4 X 3 X 3/16	8.15	3.20	12.00	9.20	0.013	
0.078	7.63	46.57	TS 7 X 3 X 3/8	22.37	13.50	50.62	7.02	0.092		0.025	5.46	10.66	TS 4 X 2 X 1/4	8.81	3.09	11.59	5.02	0.029	
0.028	16.52	45.54	TS 7 X 5 X 1/4	19.02	13.20	49.50	15.19	0.033		0.012	10.52	10.49	TS 3 X 3 X 5/16	10.58	3.04	11.40	9.68	0.014	
0.026	17.16	43.81	TS 6 X 5 X 5/16	21.21	12.70	47.62	15.79	0.031		0.008	12.70	10.11	TS 3½ X 3½ X 3/16	8.15	2.93	10.99	11.68	0.009	
0.039	12.63	43.12	TS 6 X 4 X 3/8	22.37	12.50	46.87	11.62	0.046		0.009	10.66	9.00	TS 3 X 3 X 1/4	8.81	2.61	9.79	9.81	0.011	
0.168	3.50	42.43	TS 8 X 2 X 5/16	19.08	12.30	46.12	3.22	0.199		0.018	5.61	8.56	TS 4 X 2 X 3/16	6.87	2.48	9.30	5.16	0.022	
0.070	7.38	42.09	TS 8 X 3 X 1/4	17.32	12.20	45.75	6.79	0.083		0.007	10.75	7.24	TS 3 X 3 X 3/16	6.87	2.10	7.87	9.89	0.008	
0.170	3.25	41.05*	TS 10 X 2 X 3/16	14.53	11.90	44.62*	2.99	0.201		0.013	6.16	6.62	TS 3 X 2 X 1/4	7.11	1.92	7.20	5.66	0.016	
0.017	21.90	41.05	TS 6 X 6 X 1/4	19.02	11.90	44.62	20.15	0.020		0.008	8.82	5.90	TS 2½ X 2½ X 1/4	7.11	1.71	6.41	8.12	0.009	
0.066	7.68	40.71	TS 7 X 3 X 5/16	19.08	11.80	44.25	7.06	0.079		0.010	6.28	5.42	TS 3 X 2 X 3/16	5.59	1.57	5.89	5.78	0.012	
0.036	12.13	39.67	TS 7 X 4 X 1/4	17.32	11.50	43.12	11.16	0.043		0.006	8.92	4.83	TS 2½ X 2½ X 3/16	5.59	1.40	5.25	8.20	0.007	
0.068	7.06	39.67*	TS 9 X 3 X 3/16	14.53	11.50	43.12*	6.50	0.080		0.006	6.93	3.45	TS 2 X 2 X 1/4	5.41	1.00	3.75	6.38	0.007	
0.023	17.89	38.64	TS 5 X 5 X 3/8	22.37	11.20	42.00	16.46	0.027		0.005	7.10	2.90	TS 2 X 2 X 3/16	4.32	0.84	3.15	6.53	0.005	
0.036	11.57	37.95*	TS 8 X 4 X 3/16	14.53	11.00	41.25*	10.64	0.043											
0.033	12.72	37.60	TS 6 X 4 X 5/16	19.08	10.90	40.87	11.70	0.039											
0.020	17.33	36.22	TS 6 X 5 X 1/4	17.32	10.50	39.37	15.94	0.024											
0.055	8.24	35.88	TS 6 X 3 X 3/8	19.82	10.40	39.00	7.58	0.065											
0.133	3.63	35.53	TS 8 X 2 X 1/4	15.62	10.30	38.62	3.34	0.157											
0.020	16.68	35.19	TS 7 X 5 X 3/16	14.53	10.20	38.25	15.35	0.024											
0.052	7.87	33.78	TS 7 X 3 X 1/4	15.62	9.79	36.71	7.24	0.061											
0.018	18.04	33.46	TS 5 X 5 X 5/16	19.08	9.70	36.37	16.59	0.022											
0.052	7.46	32.74*	TS 8 X 3 X 3/16	13.25	9.49	35.59*	6.86	0.062											
0.028	13.37	32.57	TS 5 X 4 X 3/8	19.82	9.44	35.40	12.30	0.033											
0.050	8.50	31.74	TS 5 X 3 X 1/2	21.63	9.20	34.50	7.82	0.060											