

A Beam Design Aid for Structural Tubing

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Structural tubing is used primarily by designers for pipe and equipment supports. Recently, tubes have also been used in other major structures. Square and rectangular structural tubes have excellent resistance to lateral torsional buckling depending on their lateral dimensions. They are also pleasing aesthetically and assure cleanliness by eliminating dirt-collecting flange areas.

The 1978 AISC Specification¹ has explicit provisions for the use of square or rectangular tubes for beams. However, there are no beam design aids in the steel manual² for tubes, other than section property information. Design aids are available however^{3,4} in the form of "Beam Load Tables" showing allowable uniform loads for laterally supported beams. The author felt a design aid similar in scope and content to the "Allowable Stress Design Selection Table" in the Manual would be of use to the steel design professional. The accompanying tables would greatly facilitate the selection of tubular flexural members designed on the

basis of allowable bending stresses in accordance with the 1978 AISC Specification.

The design aid information available here is valid for laterally supported tubular sections used as beams. It is assumed the loading is applied in the plane of the minor axis and that the beam deflects vertically in the plane of bending only.

The lateral support requirement as given in Sect. 1.5.1.4.1.6 for using $F_b = 0.66 F_y$ is: "the laterally unsupported length of the compression flange of a box-shaped member of rectangular cross section whose depth is not more than six times the width ($d \leq 6b$) and whose flange thickness is not more than two times the web thickness ($t_f \leq 2t_w$) shall not exceed the value:

$$\left(1950 + 1200 \frac{M_1}{M_2}\right) \frac{b}{F_y}$$

except that it need not be less than $1200 b/F_y$." All sections

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Table 1. Maximum Unbraced Lengths (L_c , ft) for using $F_{bx} = 0.66 F_y$

F_y ksi	M_1/M_2	Flange Width, In.											
		2	2½	3	3½	4	5	6	7	8	10	12	14
46	+1	11.4	14.2	17.1	19.9	22.8	28.5	34.2	39.9	45.6	57.0	68.4	79.8
	+0.5	9.2	11.5	13.8	16.1	18.4	23.0	27.7	32.3	36.9	46.0	55.0	64.0
	0	7.0	8.8	10.6	12.3	14.1	17.6	21.1	24.7	28.2	35.3	42.3	49.4
	-0.5	4.8	6.1	7.3	8.5	9.7	12.2	14.6	17.1	19.5	24.4	29.3	34.2
	-0.625 to -1.0	4.3	5.4	6.5	7.6	8.7	10.8	13.0	15.2	17.4	21.7	26.0	30.4
50	+1.0	10.5	13.1	15.7	18.3	21.0	26.2	31.5	36.7	42.0	52.5	63.0	73.5
	+0.5	8.5	10.6	12.7	14.8	17.0	21.2	25.5	29.7	34.0	42.5	51.0	59.5
	0	6.5	8.1	9.7	11.3	13.0	16.2	19.5	22.7	26.0	32.5	39.0	45.5
	-0.5	4.5	5.6	6.7	7.9	9.0	11.2	13.5	15.7	18.0	22.5	27.0	31.5
	-0.625 to -1.0	4.0	5.0	6.0	7.0	8.0	10.0	12.0	14.0	16.0	20.0	24.0	28.0

listed in the Manual satisfy the depth-width and flange thickness-web thickness criteria.

Table 1 gives the values of laterally unsupported lengths L_c for compression flanges varying from 2 in. through 14 in. in width and for several ratios of M_1/M_2 . The values are tabulated for steels of $F_y = 46$ ksi and $F_y = 50$ ksi.

Table 2 is the beam selection table. This table is applicable to adequately braced beams for which a value of $F_{bx} = 0.66 F_y$ is permitted by the AISC Specification. In this table the shapes are listed in groups by descending order of section modulus S_x . The maximum resisting moment, M_R , for steels of $F_y = 46$ ksi and $F_y = 50$ ksi is also listed. The lightest and most economical shape is listed at the top of each group and shown in bold face. The values of M_R are valid for beams with unbraced lengths less than or equal to L_c . Shapes not satisfying compact section requirements are excluded. These non-compact shapes lead to uneconomical design. An asterisk is placed after M_R for those sections which may become non-compact due to the presence of axial loads for not satisfying Sect. 1.5.1.4.1.4 of the Specification.

Example:

Select a structural tube shape for a simply supported beam of span 12 ft. The beam is laterally supported at the supports and at mid-span and is subjected to a maximum bending moment of 140 kip-ft. Use $F_y = 46$ ksi.

Solution:

Assume $F_b = 0.66 F_y = 30.4$ ksi.

$$S_{(reqd)} = \frac{M}{F_b} = \frac{140 \times 12}{30.4} = 55.26 \text{ in.}^3$$

Entering Table 2, it is found the nearest tabulated value of S_x is 58.9, which corresponds to a TS 12 × 8 × ½ weighing 62.46 lbs./ft. Proceeding up that specific group of shapes, the first shape in bold face is TS 18 × 6 × 5/16 with $S_x = 60.7$ in.³, weighing 48.86 lbs./ft and with $M_R = 153$ kip-ft. It represents the most economical tubular shape.

From Table 1, for tubes with $b = 6$ -in., the value of $L_c = 34.2$ ft for $M_1/M_2 = 1$, $L_c = 21.2$ ft for $M_1/M_2 = 0$, and $L_c = 13$ ft for $M_1/M_2 = -1$. For this specific case, $M_1 = 0$, $M_2 = 140$ kip-ft. Therefore, the appropriate value of $L_c = 34.2$ ft, which is more than 6 ft.

Use TS 18 × 6 × 5/16 $M_R = 153$ kip-ft.

REFERENCES

1. American Institute of Steel Construction, Inc. Specification for the Design, Fabrication and Erection of Structural Steel for Buildings 1978, Chicago, Ill.
2. American Institute of Steel Construction, Inc. Manual of Steel Construction 8th Ed., 1980, Chicago, Ill.
3. Copperweld Tubing Group Structural Steel Tubing 1982, Pittsburgh, Pa.
4. Welded Steel Tube Institute, Inc. Cold Formed Welded Structural Steel Tubing 1974, Cleveland, Ohio.

Table 2. Moment Capacities of Structural Steel Tubing

Shape	Wt., lb.	S_x , in. ³	$F_y = 46$ ksi M_R , K-ft	$F_y = 50$ ksi M_R , K-ft
TS 20 × 12 × ½	103.3	165	418*	453*
TS 20 × 8 × ½	89.68	127	321*	349*
TS 16 × 12 × ½	89.68	120	304	330
TS 14 × 14 × ½	89.68	113	286	310
TS 20 × 8 × ¾	68.31	98.8	250*	271*
TS 18 × 6 × ½	76.07	90.9	230	249
TS 16 × 8 × ½	76.07	90.2	228	248
TS 20 × 4 × ½	76.07	88.9	225*	244*
TS 14 × 10 × ½	76.07	86.9	220	238
TS 20 × 8 × ⅝	57.36	83.8	212*	230*
TS 12 × 12 × ½	76.07	80.9	204	222
TS 18 × 6 × ¾	58.1	71.3	180*	196*
TS 16 × 8 × ¾	58.1	70.6	178*	194*
TS 20 × 4 × ¾	58.1	69.9	176*	192*
TS 12 × 8 × ¾	76.33	69.7	177	191
TS 14 × 10 × ¾	58.1	68.0	172	187*
TS 10 × 10 × ¾	76.33	64.2	162	176
TS 14 × 6 × ½	62.46	60.8	154	167
TS 18 × 6 × ⅝	48.86	60.7	153*	166*
TS 16 × 4 × ½	62.46	60.2	152	165
TS 16 × 8 × ⅝	48.86	60.1	152*	165*
TS 20 × 4 × ⅝	48.86	59.6	150*	163*
TS 12 × 8 × ½	62.46	58.9	149	161
TS 10 × 10 × ½	62.46	54.2	137	149
TS 14 × 6 × ¾	47.90	48.1	121.8	132*
TS 16 × 4 × ¾	47.90	47.8	121*	131*
TS 14 × 4 × ½	55.66	47.8	121	131
TS 12 × 6 × ½	55.66	47.8	121	131
TS 12 × 8 × ¾	47.90	46.5	117	127
TS 10 × 10 × ¾	47.90	42.9	108	117
TS 14 × 6 × ⅝	40.35	41.2	104*	113*
TS 16 × 4 × ⅝	40.35	40.9	103*	112*
TS 12 × 8 × ⅝	40.35	39.8	100*	109*
TS 8 × 8 × ¾	59.32	38.3	97.0	105
TS 14 × 4 × ¾	42.79	38.2	96.7	105*
TS 12 × 6 × ¾	42.79	38.1	96.5	104
TS 12 × 4 × ½	48.85	36.8	93.2	101
TS 10 × 6 × ½	48.85	36.2	91.7	99.5
TS 14 × 6 × ¼	32.63	33.8	85.6*	92.9*
TS 8 × 8 × ½	48.85	32.9	83.3	90.4
TS 14 × 4 × ⅝	36.10	32.8	83.0*	90.2*
TS 12 × 6 × ⅝	36.10	32.6	82.5*	89.6*
TS 12 × 4 × ¾	37.69	29.6	74.9	81.4
TS 10 × 6 × ¾	37.69	29.0	73.4	79.7
TS 10 × 4 × ½	42.05	27.1	68.6	74.5
TS 14 × 4 × ¼	29.23	27.0	68.4*	74.2*
TS 12 × 6 × ¼	29.23	26.9	68.1*	73.9*
TS 8 × 8 × ¾	37.69	26.4	66.8	72.6
TS 8 × 6 × ½	42.05	25.8	65.3	70.9
TS 12 × 4 × ⅝	31.84	25.5	64.6*	70.1*
TS 10 × 6 × ⅝	31.84	25.0	63.3	68.7
TS 7 × 7 × ½	42.05	24.2	61.3	66.5
TS 8 × 8 × ⅝	31.84	22.7	57.5	62.4
TS 10 × 4 × ¾	32.58	22.0	55.7	60.5

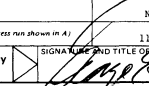
Shape	Wt., lb.	S_x , in. ³	$F_y = 46$ ksi M_R , K-ft	$F_y = 50$ ksi M_R , K-ft
TS 12 × 4 × ¼	25.82	21.1	53.4*	58.0*
TS 8 × 6 × ¾	32.58	20.9	52.9	57.4
TS 12 × 6 × ⅝	22.18	20.7	52.4*	51.7*
TS 10 × 6 × ¼	25.82	20.6	52.1*	56.6*
TS 7 × 7 × ¾	32.58	19.6	49.6	53.9
TS 10 × 4 × ⅝	27.59	19.1	48.3	52.5
TS 8 × 4 × ½	35.24	18.8	47.6	51.7
TS 8 × 6 × ⅝	27.59	18.1	45.8	49.7
TS 7 × 5 × ½	35.24	18.1	45.8	49.7
TS 7 × 7 × ⅝	27.59	17.0	43.0	46.7
TS 6 × 6 × ½	35.24	16.8	42.5	46.2
TS 12 × 4 × ¾	19.63	16.4	41.5*	45.1*
TS 10 × 4 × ¼	22.42	15.9	40.2*	43.7*
TS 8 × 4 × ¾	27.48	15.5	39.2	42.6
TS 12 × 2 × ¼	22.42	15.4	39.0*	42.3*
TS 10 × 2 × ¾	27.48	15.1	38.2	41.5
TS 8 × 6 × ¼	22.42	15.0	38.0	41.2
TS 7 × 5 × ¾	27.48	14.9	37.7	40.9
TS 6 × 6 × ¾	27.48	13.9	35.2	38.2
TS 8 × 4 × ⅝	23.34	13.5	34.2	37.1
TS 10 × 2 × ⅝	23.34	13.2	33.4	36.3
TS 7 × 5 × ⅝	23.34	13.0	32.9	35.7
TS 8 × 3 × ¾	24.93	12.7	32.1	34.9
TS 7 × 4 × ¾	24.93	12.6	31.9	34.6
TS 10 × 4 × ¾	17.08	12.3	31.1*	33.8*
TS 6 × 6 × ⅝	23.34	12.1	30.6	33.2
TS 12 × 2 × ⅝	17.08	12.0	30.4*	33.0*
TS 6 × 4 × ½	28.43	11.8	29.8	32.4
TS 8 × 6 × ⅝	17.08	11.7	29.6*	32.1*
TS 8 × 4 × ¼	19.02	11.3	28.6	31.0
TS 8 × 3 × ⅝	21.21	11.2	28.3	30.8
TS 10 × 2 × ¼	19.02	11.1	28.1*	30.5*
TS 7 × 4 × ⅝	21.21	11.0	27.8	30.2
TS 7 × 5 × ¼	19.02	10.9	27.6	29.9
TS 5 × 5 × ½	28.43	10.8	27.3	29.7
TS 7 × 3 × ¾	22.37	10.2	25.8	28.0
TS 6 × 6 × ¼	19.02	10.1	25.5	27.7
TS 8 × 2 × ¾	22.37	10.0	25.3	27.5
TS 6 × 4 × ¾	22.37	9.9	25.0	27.2
TS 8 × 3 × ¼	17.32	9.4	23.8	25.8
TS 7 × 4 × ¼	17.32	9.23	23.3	25.3
TS 5 × 5 × ¾	22.37	9.11	23.0	25.0
TS 7 × 3 × ⅝	19.08	9.0	22.8	24.7
TS 8 × 2 × ⅝	19.08	8.87	22.4	24.3
TS 8 × 4 × ¾	14.53	8.83	22.3*	24.2*
TS 10 × 2 × ⅝	14.53	8.74	22.1*	24.0*
TS 6 × 4 × ⅝	19.08	8.72	22.0	23.9
TS 7 × 5 × ⅝	14.53	8.5	21.5	23.4*
TS 5 × 5 × ⅝	19.08	8.02	20.3	21.8
TS 6 × 3 × ¾	19.82	7.92	20.0	21.7
TS 7 × 3 × ¼	15.62	7.61	19.2	20.9
TS 8 × 2 × ¼	15.62	7.52	19.0	20.6
TS 5 × 4 × ¾	19.82	7.50	19.0	20.6

*Signifies capacity may have to be reduced (i.e. $F_{bx} = 0.6 F_y$) when axial loads are present to satisfy AISC 1.5.1.4.1.4.

Table 2. (continued)

Shape	Wt., lb.	S_x , in. ³	$F_y = 46$ ksi	$F_y = 50$ ksi
			M_R , K-ft	M_R , K-ft
TS 8 × 3 × 3/16	13.25	7.40	18.7*	20.3*
TS 6 × 4 × 1/4	15.62	7.36	18.6	20.2
TS 7 × 4 × 3/16	13.25	7.26	18.3	19.9*
TS 6 × 3 × 3/16	16.96	7.03	17.8	19.2
TS 5 × 5 × 1/4	15.62	6.78	17.1	18.6
TS 5 × 3 × 1/2	21.63	6.75	17.1	18.5
TS 5 × 4 × 3/16	16.96	6.65	16.8	18.2
TS 4 × 4 × 1/2	21.63	6.13	15.5	16.8
TS 7 × 3 × 3/16	11.97	6.02	15.2	16.5*
TS 6 × 3 × 1/4	13.91	5.98	15.1	16.4
TS 8 × 2 × 3/16	11.97	5.97	15.1*	16.4*
TS 6 × 2 × 3/8	17.27	5.94	15.0	16.3
TS 5 × 3 × 3/8	17.27	5.89	14.9	16.1
TS 6 × 4 × 3/16	11.97	5.81	14.7	15.9
TS 5 × 4 × 1/4	13.91	5.65	14.3	15.5
TS 5 × 5 × 3/16	11.97	5.36	13.5	14.7
TS 4 × 4 × 3/8	17.27	5.35	13.5	14.7
TS 6 × 2 × 5/16	14.83	5.34	13.5	14.6
TS 5 × 3 × 3/16	14.83	5.27	13.3	14.4
TS 4 × 4 × 5/16	14.83	4.79	12.1	13.1
TS 6 × 3 × 3/16	10.70	4.76	12.0	13.0
TS 6 × 2 × 1/4	12.21	4.60	11.6	12.6
TS 5 × 3 × 1/4	12.21	4.52	11.4	12.4
TS 5 × 4 × 3/16	10.70	4.49	11.3	12.3
TS 4 × 4 × 1/4	12.21	4.11	10.4	11.3
TS 5 × 2 × 5/16	12.70	3.90	9.88	10.7
TS 4 × 3 × 5/16	12.70	3.72	9.42	10.2
TS 3.5 × 3.5 × 5/16	12.70	3.48	8.81	9.5
TS 6 × 2 × 3/16	9.42	3.70	9.37	10.1
TS 5 × 3 × 3/16	9.42	3.62	9.17	9.95
TS 5 × 2 × 1/4	10.51	3.39	8.58	9.32
TS 4 × 4 × 3/16	9.42	3.30	8.36	9.07
TS 4 × 3 × 1/4	10.51	3.23	8.18	8.88
TS 3.5 × 3.5 × 1/4	10.51	3.02	7.65	8.30
TS 5 × 2 × 3/16	8.15	2.75	6.96	7.56
TS 4 × 2 × 5/16	10.58	2.66	6.73	7.31
TS 4 × 3 × 3/16	8.15	2.62	6.63	7.20
TS 3.5 × 3.5 × 3/16	8.15	2.45	6.20	6.73
TS 3 × 3 × 5/16	10.58	2.39	6.05	6.57
TS 4 × 2 × 1/4	8.81	2.35	5.95	6.46
TS 3 × 3 × 1/4	8.81	2.10	5.32	5.77
TS 4 × 2 × 3/16	6.87	1.93	4.88	5.30
TS 3 × 3 × 3/16	6.87	1.73	4.38	4.75
TS 3 × 2 × 1/4	7.11	1.47	3.72	4.04
TS 2.5 × 2.5 × 1/4	7.11	1.35	3.42	3.71
TS 3 × 2 × 3/16	5.59	1.24	3.14	3.41
TS 2.5 × 2.5 × 3/16	5.59	1.14	2.88	3.13
TS 2 × 2 × 1/4	5.41	0.766	1.94	2.10
TS 2 × 2 × 3/16	4.32	0.668	1.69	1.83

*Signifies capacity may have to be reduced (i.e. $F_{bx} = 0.6 F_y$) when axial loads are present to satisfy AISC 1.5.1.4.1.4.

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