

Manual of Steel Construction

Load and Resistance Factor Design, 3rd Edition

Part 1

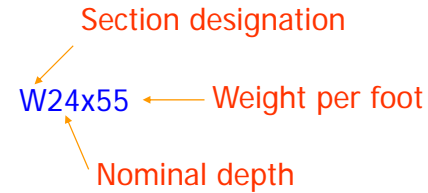
Dimensions and Properties

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Wide-flange (W) Shapes

- Most widely used section
- Two flanges held apart by a web
- Essentially parallel inner and outer flange surfaces



Major (strong) axis
Flange
Web
Minor (weak) axis
Designation

Table 1-1. W-Shapes Dimensions

Shape	Area, A	Depth, d	Web		Flange		Distance			Workable Gage ¹					
			Thickness, t _w	t _w /2	Width, b _f	Thickness, t _f	k	k ₁	T						
											in.	in.	in.	in.	in.
W44x335	98.3	44.0	44	1.02	1	1/2	16.0	16	1.77	1 3/4	2.56	2 5/8	1 5/16	38 3/4	5 1/2
x290	85.8	43.6	43 5/8	0.870	7/8	7/16	15.8	15 7/8	1.58	1 5/8	2.37	2 7/16	1 1/4	36 3/4	5 1/2
x262	77.2	43.3	43 1/4	0.790	19/16	7/16	15.8	15 3/4	1.42	1 7/16	2.21	2 1/4	1 3/16	36 3/4	5 1/2
x238	67.7	42.9	42 7/8	0.710	1 1/16	3/8	15.8	15 3/4	1.22	1 1/4	2.01	2 1/16	1 3/16	36 3/4	5 1/2

Cross-sectional area
Actual depth
Designation

Table 1-1. W-Shapes Dimensions

Shape	Area, A	Depth, d	Web		Flange		Distance			Workable Gage ¹					
			Thickness, t _w	t _w /2	Width, b _f	Thickness, t _f	k	k ₁	T						
											in.	in.	in.	in.	in.
W44x335	98.3	44.0	44	1.02	1	1/2	16.0	16	1.77	1 3/4	2.56	2 5/8	1 5/16	38 3/4	5 1/2
x290	85.8	43.6	43 5/8	0.870	7/8	7/16	15.8	15 7/8	1.58	1 5/8	2.37	2 7/16	1 1/4	36 3/4	5 1/2
x262	77.2	43.3	43 1/4	0.790	19/16	7/16	15.8	15 3/4	1.42	1 7/16	2.21	2 1/4	1 3/16	36 3/4	5 1/2
x238	67.7	42.9	42 7/8	0.710	1 1/16	3/8	15.8	15 3/4	1.22	1 1/4	2.01	2 1/16	1 3/16	36 3/4	5 1/2

Table 1-1. W-Shapes Dimensions

Web thickness
Flange properties

Shape	Area, A	Depth, d	Web		Flange		Distance			Weldable Gaps ¹		
			Thickness, t _w	t _w /2	Width, b _f	Thickness, t _f	k	d ₁	T			
	in. ²	in.	in.	in.	in.	in.	in.	in.	in.	in.		
W44x338 ²	98.3	44.0	1.82	1	17.0	1.77	1 3/4	2.56	2 5/8	1 5/8	38 3/4	5 1/2
x280	65.8	43.8	1.87	1 7/8	15.8	1.86	1 3/8	2.27	2 7/8	1 1/4	38 3/4	5 1/2
x262	77.2	43.9	1.79	1 1/2	15.8	1.82	1 7/8	2.21	2 1/2	1 3/8	38 3/4	5 1/2
x230	67.7	42.9	1.70	1 1/8	15.8	1.77	1 1/4	2.01	2 1/8	1 3/8	38 3/4	5 1/2

Table 1-1. W-Shapes Dimensions

End of fillet transition between web and flange
Flat portion of web

Shape	Area, A	Depth, d	Web		Flange		Distance			Weldable Gaps ¹		
			Thickness, t _w	t _w /2	Width, b _f	Thickness, t _f	k	d ₁	T			
	in. ²	in.	in.	in.	in.	in.	in.	in.	in.	in.		
W44x338 ²	98.3	44.0	1.82	1	16.0	1.77	1 3/4	2.56	2 5/8	1 5/8	38 3/4	5 1/2
x280	65.8	43.8	1.87	1 7/8	15.8	1.86	1 3/8	2.27	2 7/8	1 1/4	38 3/4	5 1/2
x262	77.2	43.9	1.79	1 1/2	15.8	1.82	1 7/8	2.21	2 1/2	1 3/8	38 3/4	5 1/2
x230	67.7	42.9	1.70	1 1/8	15.8	1.77	1 1/4	2.01	2 1/8	1 3/8	38 3/4	5 1/2

Spacing between rows of bolts in flange

Second moment, elastic section modulus, radius of gyration, plastic section modulus for strong and weak axes

Table 1-1 (cont.). W-Shapes Properties

Weight per foot
Flange and web stability parameters

Nominal Wt.	Compact Section Criteria			X ₁	X ₂ × 10 ⁶	Axis X-X				Axis Y-Y			
	b _f /2t _f	h/t _w	F _y /F _y			I	S	r	Z	I	S	r	Z
lb/ft			ksi	ksi	(1/ksi) ²	in. ⁴	in. ³	in.	in. ³	in. ⁴	in. ³	in.	in. ³
935	4.51	26.1	44.3	2430	5110	31100	1410	17.8	1620	1200	151	3.50	288
297	5.01	44.7	32.2	2150	8170	27100	1240	17.8	1420	1050	132	3.49	206
262	5.55	49.2	26.6	1930	12300	24200	1120	17.7	1270	927	118	3.46	183
230	6.45	54.8	21.5	1690	21100	20800	971	17.5	1100	796	101	3.43	157

Used for beam strength calculations

M-Shapes

- Not classified in ASTM 6 as W-, S- or HP- shapes
- Same properties (A, d, t_w, b_f, etc) as W- shapes

HP-Shapes

- Also known as bearing piles
- Similar to W-shapes, except their webs and flanges are of equal thickness and the depth and flange width are nominally equal for a given designation

American Standard (S) Shapes

- 16-2/3% slope on inner flange surface

Section designation
S24x121 ← Weight per foot
 Nominal depth

- Relatively narrow flange when compared to W shapes

Table 1-3. S-Shapes (American Standard Beams) Dimensions

Shape	Area, A in. ²	Depth, d in.		Web Thickness, t_w in.		Flange Width, b_f in.		Flange Thickness, t_f in.		Distance in.		
		21	24	13/16	5/8	8.05	7.87	1.09	1.09	k	T	Workable Gage† in.
S24x121	36.5	21.5	21 1/2	0.800	13/16	8.05	8	1.09	1 1/16	2	20 1/2	4
x106	31.1	24.5	24 1/2	0.620	5/8	7.87	7 7/8	1.09	1 1/16	2	20 1/2	4

Same properties as for W shapes

Table 1-3 (cont.). S-Shapes (American Standard Beams) Properties

Nominal Wt. lb/ft	Compact Section Criteria			X_1 ksi	$X_2 \times 10^6$ (1/ksi) ²	Axis X-X				Axis Y-Y			
	b_f 2t _f	h t _w	F_y^{III} ksi			I	S	r	Z	I	S	r	Z
						in. ⁴	in. ³	in.	in. ³	in. ⁴	in. ³	in.	in. ³
121	3.69	25.9	—	3310	1770	3160	258	9.43	306	83.0	20.6	1.53	36.3
106	3.61	33.4	57.8	2960	2470	2940	240	9.71	279	76.8	19.5	1.57	33.4

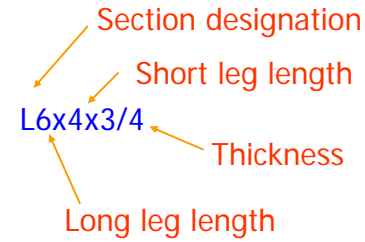
Channels

- 16-2/3% slope on inner flange surface

Section designation
C15x50 ← Weight per foot
 Actual depth

MC – Miscellaneous channel – 2 on 12 slope on inner flange

Angles



- Major axes do not correspond to X and Y axes

Table 1-5. C-Shapes (American Standard Channels) Dimensions

Shape	Area, A in. ²	Depth, d		Web		Flange		Distance			Workable Gage† in.		
		in.	in.	Thickness, tw in.	tw/2 in.	Width, bf in.	Thickness, tf in.	k in.	T in.				
C15x50	14.7	15.0	15	0.716	11/16	3/8	8.72	3 3/4	0.650	5/8	1 7/16	12 1/8	2 1/4
x40	11.8	0.520	1/2	1/4	3.52	3 1/2							2 2
x33.9	9.95	0.400	3/8	3/16	3.40	3 3/8							2 2

Table 1-7. Angles (L-Shapes) Properties

Shape	k in.	Wt. lb/ft	Area, A in. ²	Axis X-X					yp in.
				i in.	S in. ³	r in.	Y-bar in.	Z in.	
LBx8x1 1/8	1 3/4	57.2	16.8	98.1	17.5	2.41	2.40	31.6	1.05
x1	1 5/8	51.3	15.1	89.1	15.8	2.43	2.36	28.5	0.943
x7/8	1 1/2	45.3	13.3	79.7	14.0	2.45	2.31	25.3	0.832
x3/4	1 3/8	39.2	11.5	69.9	12.2	2.46	2.26	22.0	0.720
x5/8	1 1/4	33.0	9.69	59.6	10.3	2.48	2.21	18.6	0.606
x9/16	1 3/16	29.8	8.77	54.2	9.33	2.49	2.19	16.8	0.548
x1/2	1 1/8	26.7	7.84	48.8	8.36	2.49	2.17	15.1	0.490

Table 1-7 (cont.). Angles (L-Shapes) Properties

Shape	Axis Y-Y					Axis Z-Z		Qs*
	I in. ⁴	S in. ³	r in.	X-bar in.	Z in.	r in.	Tan alpha	
LBx8x1 1/8	96.1	17.5	2.41	2.40	31.6	1.05	1.56	1.00
x1	80.1	15.8	2.43	2.36	28.5	0.943	1.56	1.00
x7/8	79.7	14.0	2.45	2.31	25.3	0.832	1.57	1.00
x3/4	69.9	12.2	2.46	2.26	22.0	0.720	1.57	1.00
x5/8	59.6	10.3	2.48	2.21	18.6	0.606	1.58	1.00
x9/16	54.2	9.33	2.49	2.19	16.8	0.548	1.58	1.00
x1/2	48.8	8.36	2.49	2.17	15.1	0.490	1.59	1.00

Tees

- WT – cut from W shape

WT22x131 is cut from W44x262

- ST – cut from S shape

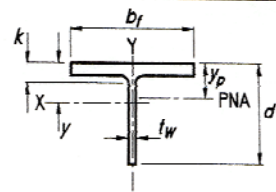
- MT – cut from M shape

Table 1-8. WT-Shapes (Structural Tees Split from W-Shapes) Dimensions

Shape	Area, A in. ²	Depth of Tee, d in.	Stem			Flange			Distance					
			Thickness, t _w in.	t _w /2 in.	Area in. ²	Width, b _f in.	Thickness, t _f in.	k in.	in.	Workable Gauge ^f in.				
			in.	in.	in. ²	in.	in.	in.	in.					
WT22 x 167.5*	49.1	22.0	22	1.02	1	1/2	22.5	16.0	1.6	1.77	1 3/4	2.56	2 5/8	5 1/8
x 145	42.9	21.8	21 3/4	0.870	7/8	7/16	19.0	15.8	1.5	1.58	1 9/16	2.37	2 7/8	5 1/8
x 131	38.6	21.7	21 5/8	0.790	13/16	7/16	17.1	15.8	1.42	1 7/16	2.21	2 1/4	2 1/4	5 1/8
x 115	33.8	21.5	21 1/2	0.710	1 1/16	3/8	15.2	15.8	1.22	1 1/4	2.01	2 1/8	2 1/8	5 1/8

Stem, not web

Table 1-8 (cont.). WT-Shapes (Structural Tees Split from W-Shapes) Properties



Nominal Wt. lb/ft	h/t _w	Axis X-X						Axis Y-Y				Q _s ** F _y = 50 ksi
		I	S	r	ȳ	Z	y _p	I	S	r	Z	
		in. ⁴	in. ³	in.	in.	in. ³	in.	in. ⁴	in. ³	in.	in. ³	
167.5	19.1	2160	131	6.63	5.51	253	1.54	600	75.3	3.50	118	0.817
145	22.3	1840	111	6.55	5.27	197	1.35	523	65.1	3.49	103	0.636
131	24.6	1650	100	6.53	5.20	177	1.23	463	58.8	3.46	91.3	0.532
115	27.4	1440	88.6	6.53	5.17	157	1.07	398	50.5	3.43	79.3	0.438

Reduction factor for slender stiffened compression elements

Hollow Structural Shapes (HSS)

- Rectangular (or square)
- Round

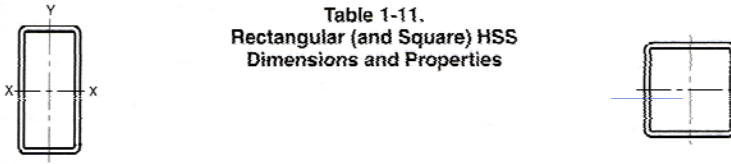
Steel Pipe

Pipe diameter (Std., X-Strong, XX-Strong)

For example, Pipe 5 Std.

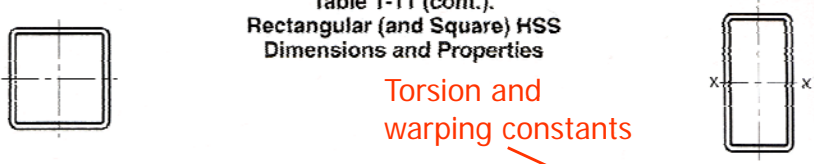
Hollow Structural Shapes (HSS)

Table 1-11. Rectangular (and Square) HSS Dimensions and Properties



Shape	Wall Thickness, t		Nominal Wt. lb/ft	Area, A in. ²	$\frac{b}{t}$	$\frac{h}{t}$	Axis X-X			
	nominal	design					I	S	r	Z
	in.	in.								
HSS20x12	5/8	0.501	12.7	35.0	17.7	31.4	1980	188	7.33	230
	1/2	0.485	10.3	28.3	22.8	40.0	1550	155	7.39	188
	3/8	0.349	78.4	21.5	31.4	54.3	1200	120	7.45	144
	5/16	0.291	65.8	18.1	38.2	65.7	1010	101	7.48	122

Table 1-11 (cont.). Rectangular (and Square) HSS Dimensions and Properties




Torsion and warping constants

Shape	Wall Thickness, t		Axis Y-Y				Torsion		Surface Area Per Foot ft ²
	nominal	design	I	S	r	Z	J	C	
	in.	in.							
HSS20x12	5/8	0.581	851	142	4.93	162	1890	257	5.17
	1/2	0.465	705	117	4.99	132	1540	209	5.20
	3/8	0.349	547	91.1	5.04	102	1180	160	5.23
	5/16	0.291	464	77.3	5.07	85.6	997	134	5.25

Diameter over design thickness

Nominal versus design thickness

Table 1-12. Round HSS Dimensions and Properties



Shape	Wall Thickness, t		Nominal Wt. lb/ft	Area, A in. ²	$\frac{D}{t}$	I in. ⁴	S in. ³	r in.	Z in. ³	Torsion		Surf. Area Per Ft ft ²
	nominal	design								J in. ⁴	C in. ³	
	in.	in.										
HSS20.000	0.500	0.485	104	28.5	43.0	1360	136	6.91	177	2720	272	5.24
	0.375	0.349	78.7	21.5	57.3	1040	101	6.95	135	2080	208	5.24

Double Angles

2L6x4x3/4

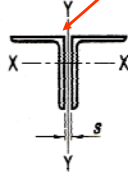
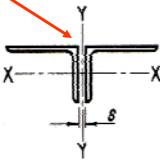
- Major axes are now x and y
- X axis properties may be obtained from x axis properties of single angle
- Y axis properties depend on separation between backs angles and whether LLBB or SLBB

Equal leg angles

Long legs back-to-back

Short legs back-to-back

Table 1-14. Double Angles (2L-Shapes) Properties

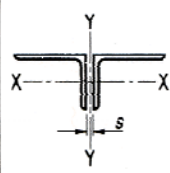
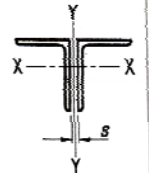



Shape	Axis Y-Y Radii of Gyration						Q_s^*			
	LLBB			SLBB			LLBB		SLBB	
	Separation s, in.						Angles in Contact	Angles Separated	Angles in Contact	Angles Separated
	0	3/8	3/4	0	3/8	3/4				
2L6x6x1 1/8	3.41	3.54	3.68	3.41	3.54	3.68	-	-	-	-
x1	3.39	3.52	3.66	3.39	3.52	3.66	-	-	-	-
x7/8	3.36	3.50	3.63	3.36	3.50	3.63	-	-	-	-
x3/4	3.34	3.47	3.61	3.34	3.47	3.61	-	-	-	-
x5/8	3.32	3.45	3.58	3.32	3.45	3.58	-	0.997	-	0.997
x9/16	3.31	3.44	3.57	3.31	3.44	3.57	-	0.959	-	0.959
x1/2	3.30	3.43	3.56	3.30	3.43	3.56	0.998	0.912	0.988	0.912

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Unequal leg angles

Table 1-14 (cont.). Double Angles (2L-Shapes) Properties

Shape	Axis Y-Y Radii of Gyration						Q_s^*			
	LLBB			SLBB			LLBB		SLBB	
	Separation s, in.						Angles in Contact	Angles Separated	Angles in Contact	Angles Separated
	0	3/8	3/4	0	3/8	3/4				
2L5x3 1/2x3/4	1.39	1.53	1.68	2.33	2.47	2.62	-	-	-	-
x5/8	1.37	1.50	1.65	2.30	2.45	2.59	-	-	-	-
x1/2	1.35	1.48	1.62	2.26	2.42	2.57	-	-	-	-
x3/8	1.33	1.46	1.59	2.26	2.39	2.54	-	0.983	-	0.983
x5/16	1.32	1.44	1.58	2.25	2.38	2.52	-	0.912	-	0.912
x1/4	1.31	1.43	1.57	2.23	2.37	2.51	-	0.804	-	0.804

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Double Channels

- Designated as 2C or 2MC

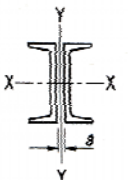
2C15x50

- Y axis properties depend on back to back separation
- X axis properties can be obtained from x axis properties of single channel

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Y axis properties depend on back-to-back distance between individual channels

Table 1-15. 2C-Shapes (Double Channels) Properties

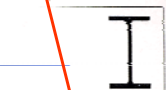


Shape	Axis Y-Y Separation s, in.											
	0						3/8			3/4		
	I	S	r	Z	I	S	r	Z	I	S	r	Z
	in. ⁴	in. ³	in.	in. ³	in. ⁴	in. ³	in.	in. ³	in. ⁴	in. ³	in.	in. ³
2C15x50	40.7	11.0	1.18	30.7	50.5	12.9	1.31	38.2	62.4	15.3	1.46	41.7
x40	32.6	9.25	1.18	22.9	40.2	10.9	1.31	27.3	49.6	12.7	1.45	31.7
x33.9	28.5	8.38	1.20	19.0	35.1	9.78	1.33	22.7	43.1	11.4	1.47	26.1

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$$\frac{VQ}{Ib}$$

Table 1-25. W-Shapes Torsional Properties



Shape	Torsional Constant, J	Warping Constant, C_w	$\sqrt{EC_w/GJ}$	Normalized Warping Constant, W_{no}	Warping Statical Moment, S_w	Statistical Moment	
	in. ⁴	in. ⁶	in.	in. ²	in. ⁴	Q_f in. ³	Q_w in. ³
W44 x 335*	74.4	536000	137	168	1190	276	305
x290	51.5	464000	153	166	1040	249	704
x262	37.7	407000	167	165	932	222	630
x230	24.9	346000	190	164	789	191	546

Table 2-1. Applicable ASTM Specifications for Various Structural Shapes

Steel Type	ASTM Designation	F_y Min. Yield Stress (ksi)	F_u Tensile Stress* (ksi)	Applicable Shape Series													
				W	M	S	HP	C	MC	L	Rect. HSS	Round Steel Pipe					
Carbon	A36	36	58-60 ^a														
	A500	Gr. B	42	58													
		Gr. C	46	58													
		Gr. 50	50	62													
	A501	36	58														
High-Strength Low-Alloy	A529 ^b	Gr. 50	50	65-100													
		Gr. 55	55	70-100													
	A572	Gr. 42	42	60													
		Gr. 50	50	65 ^d													
		Gr. 55	55	70													
		Gr. 60 ^a	60	75													
	A618 ^b	Gr. 65 ^a	65	80													
		Gr. I & II	50 ^c	70 ^c													
		Gr. III	50	65													
		50	50 ^a	60 ^a													
60		60	75														
A913	65	65	80														
	70	70	90														
	70	70	90														
A992	50-65 ^e	65 ^e															
Corrosion Resistant High-Strength Low-Alloy	A242	42	63 ^f														
		46 ^f	67 ^f														
	A588	50	70 ^g														
	A847 ^h	50	70														

■ = Preferred material specification.
 □ = Other applicable material specification, the availability of which should be confirmed prior to specification.
 ◻ = Material specification does not apply.

Applicable ASTM Specifications/ Shapes

Applicable ASTM Specifications /Fasteners

Table 2-5. Applicable ASTM Specifications for Various Types of Structural Fasteners

ASTM Designation	F_y Min. Yield Stress (ksi)	F_u Tensile Stress* (ksi)	Diameter Range (in.)	High-Strength Bolts										Anchor Rods		
				Conventional	Twist-Off-Type	Common Bolts	Hex	Washers	Strength-Indicator Washers	Threaded Rods	Shear Stud Connections	Headed	Headed & Waffled	Headed	Threaded & Waffled	
A156	65	90	0.375 to 0.75, incl.													
A325 ^a	105	125	over 1 to 1.5, incl.													
A490	120	150	0.5 to 1, incl.													
F1662	105	120	0.5 to 1, incl.													
A194 Gr. 2H	—	—	0.25 to 4													
A953	—	—	0.25 to 4													
F-430 ^b	—	—	0.25 to 4													
F959	—	—	0.5 to 1.5													
A56	36	58-60	to 70													
A193 Gr. B7 ^c	—	100	over 4 to 7													
Gr. A	—	115	over 2.5 to 4													
	—	125	2.5 and under													
Gr. C	—	95	0.25 to 4													
	—	58-80	0.25 to 4													
A254 Ex. B0	—	140	2.5 to 4, incl.													
A448	—	150	0.25 to 2.5, incl.													
	—	90	1.75 to 3, incl.													
Gr. 42	—	95	1.125 to 1.5, incl.													
	—	120	0.25 to 1, incl.													
A572	Gr. 42	42	to 4													
	Gr. 50	50	to 4													
	Gr. 55	55	to 2													
	Gr. 60	60	to 1.25													
A588	Gr. 65	65	to 1.25													
	42	53	Over 5 to 8, incl.													
	46	67	Over 4 to 5, incl.													
A882	50	70	4 and under													
	105	150 max.	0.625 to 3													
	Gr. 36	36	0.5 to 6													
F1554	Gr. 55	55	0.25 to 4													
	Gr. 105	105	0.25 to 3													

■ = Preferred material specification.
 □ = Other applicable material specification, the availability of which should be confirmed prior to specification.
 ◻ = Material specification does not apply.

Size Groupings

Structural Shape Size Groupings for Tensile Property Classification

Structural Shapes	Group 1	Group 2	Group 3	Group 4	Group 5
W Shapes	W 24 x 55, 62 W 21 x 44 to 57 incl. W 18 x 35 to 71 incl. W 16 x 25 to 57 incl. W 14 x 22 to 53 incl. W 12 x 14 to 50 incl. W 8 x 10 to 48 incl. W 0 x 9 to 50 incl. W 5 x 16, 19 W 4 x 13	W 44 x 244 W 40 x 49 to 268 incl. W 36 x 135 to 210 incl. W 33 x 118 to 152 incl. W 30 x 90 to 211 incl. W 27 x 84 to 178 incl. W 24 x 68 to 162 incl. W 21 x 62 to 117 incl. W 18 x 78 to 143 incl. W 16 x 67 to 100 incl. W 14 x 51 to 132 incl. W 12 x 65 to 106 incl. W 10 x 49 to 112 incl. W 8 x 58, 67	W 44 x 248, 285 W 40 x 227 to 328 incl. W 36 x 230 to 300 incl. W 33 x 201 to 291 incl. W 30 x 235 to 281 incl. W 27 x 194 to 251 incl. W 24 x 168 to 258 incl. W 21 x 142 to 229 incl. W 18 x 117 to 223 incl. W 16 x 145 to 192 incl. W 14 x 145 to 211 incl. W 12 x 120 to 190 incl.	W 40 x 362 to 655 incl. W 36 x 328 to 798 incl. W 33 x 318 to 919 incl. W 30 x 292 to 581 incl. W 27 x 281 to 539 incl. W 24 X 250 to 492 incl. W 21 x 248 to 402 incl. W 18 x 211 to 311 incl. W 12 x 210 to 336 incl.	W 36 x 848 W 14 x 606 to 730 incl.
M Shapes	to 37.7 lb/ft incl.				
S Shapes	to 35 lb/ft incl.				
HP Shapes					
American Standards Channels (C)	to 20.7 lb/ft incl.	to 102 lb/ft incl.	over 102 lb/ft		
Miscellaneous Channels (MC)	to 28.5 lb/ft incl.	over 20.7 lb/ft	over 28.5 lb/ft		
Angles (L)	to 1/2 in. incl.	lb/ft over 1.2, to 3/4 in. incl.	over 3/4 in.		
Structural Bar-size					

Notes: Structural tees from W, M, and S shapes fall into same group as the structural shape from which they are cut. Group 4 and Group 5 shapes are generally contemplated as columns or compression components. When used in other applications (e.g., trusses) and when thermal cutting or welding is required, special material specification and fabrication procedures apply to minimize the possibility of cracking.