Big-Time Shapes

BY JIE ZUO

Larger W-shapes, HP-shapes and angle sizes offer designers new opportunities to go big.

Dimensions											
Shape	Area, A	Depth, d	Web		Flange		Distance				
			Thickness, t_w	$t_w/2$	Width, b_f	Thickness, t_f	k		k_1	T	Workable Gage
							k_{des}	k_{det}			
	in.^{2}	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
W14×873	257	23.6	3.94	1.97	18.8	5.51	6.11	6¾	3⅛	10⅛	3–7½–3
W14×808	238	22.8	3.74	1.87	18.6	5.12	5.72	6⅜	3 1/16	10⅛	3–7½–3
W21×275	81.0	24.1	1.22	0.610	12.9	2.20	2.70	3⅛	1 7/16	18	5½
W21×248	73.1	23.7	1.10	0.550	12.8	2.00	2.50	2⅞	1⅜	18	5½
W21×223	65.7	23.4	1.00	0.500	12.7	1.80	2.30	2⅝	1 5/16	18	5½
W36×925	272	43.1	3.02	1.51	18.6	4.53	5.48	5¾	2 11/16	31½	7½
W36×853	251	43.1	2.52	1.26	18.2	4.53	5.48	5¾	2 7/16	31½	7½
W36×802	236	42.6	2.38	1.19	18.0	4.29	5.24	5½	2⅜	31½	7½
W36×723	213	41.8	2.17	1.09	17.8	3.90	4.85	5⅛	2¼	31½	7½
W40×655	193	43.6	1.97	0.985	16.9	3.54	4.72	4¾	2 3/16	34	7½

Properties														
Shape	Compact Section Criteria		Axis X-X				Axis Y-Y				r_{ts}	h_o	Torsional Properties	
	$b_f/2t_f$	h/t_w	I	S	r	Z	I	S	r	Z			J	C_w
			in.^{4}	in.^{3}	in.	in.^{3}	in.^{4}	in.^{3}	in.	in.^{3}	in.	in.	in.^{4}	in.^{6}
W14×873	1.71	2.89	18200	1540	8.42	2030	6170	655	4.90	1020	6.02	18.1	2270	505000
W14×808	1.82	3.05	16000	1400	8.20	1840	5550	596	4.83	930	5.92	17.7	1840	435000
W21×275	2.93	15.3	7630	633	9.71	742	790	121	3.12	191	3.70	21.9	101	94700
W21×248	3.20	17.0	6770	571	9.62	664	701	109	3.10	170	3.65	21.7	75.3	82500
W21×223	3.53	18.8	6010	514	9.56	594	616	96.0	3.06	150	3.60	21.6	55.1	71900
W36×925	2.05	10.6	72900	3390	16.4	4130	4940	530	4.26	862	5.30	38.5	1450	1830000
W36×853	2.01	12.7	69900	3250	16.7	3920	4600	504	4.28	805	5.22	38.5	1250	1700000
W36×802	2.10	13.5	64800	3040	16.6	3660	4210	467	4.22	744	5.15	38.3	1060	1540000
W36×723	2.28	14.8	57300	2740	16.4	3270	3700	415	4.17	659	5.06	37.9	795	1330000
W40×655	2.39	17.3	56600	2600	17.1	3080	2870	339	3.86	542	4.70	40.1	589	1150000

Table 1: Dimensions and Properties of Heavy W-Shapes

TODAY'S STRUCTURES are being asked to do more with less. Designers are working to create lighter structures using fewer materials, while at the same time pushing them to be longer, taller and more resilient than ever, not to mention more complex.

When it comes to structural steel, two producers, Nucor-Yamato Steel and ArcelorMittal, have responded to this demand for increased efficiency by adding larger structural shapes to their catalogues over the last couple of years. These heavier wide-flange shapes, deeper and heavier HP-shapes and larger angles have recently been adopted into ASTM A6/A6M *Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling*.

Wide-Flange

On the wide-flange side, ten new sizes have been added to ASTM A6. Two shapes to note are the W14×873, which has a flange thickness of 5.5 in., and the heaviest section per linear foot: the W36×925. The list of nominal depths remains the same and the maximum nominal depth of W-shapes remains 44 in. However, the actual depths of these heavier shapes continue to increase; for example, the W14×873 is actually 23.6 in. deep.

The usual material grade for these new sizes is ASTM A992. Alternative grades and higher strengths may also be available; availability and delivery times should be confirmed before specifying these sections and alternative grades. When a design is not controlled by a serviceability limit state, such as vibration or deflection, these shapes can be very efficient in terms of strength and weight. They have been successfully used in columns, trusses, outriggers and belt trusses around the world. Examples of such structures include One World Trade Center in New York and the Dallas Cowboys Stadium in Arlington, Texas.

To facilitate designing with these shapes, the section properties are provided in Table 1. Also provided are axial compression tables (Table 2), which are an extension of Table 4-1 in the AISC 14th Edition *Steel Construction Manual*, including two of the new W-shapes. The rest of the axial compression tables for the new W-shapes can be found at **www.aisc.org/largeWandL**.

HP-Shapes

New sections have been added to ASTM A6, including both heavier HP-shapes and new HP16 and HP18 cross sections. These new shapes will improve pile capacities and also may be useful as building columns. HP-shapes have thicker webs and may require fewer stiffeners and doublers. Dimensions and properties for these shapes are included in the 14th Ed. AISC *Manual*.

Angles

Structural angles larger than 8 in. are now being produced and also have been adopted into ASTM A6. The maximum leg dimension on an equal-leg angle is now 12 in. with a maximum thickness of 1⅜ in. Six 10-in. angles and four 12-in. angles have been introduced and are available to be ordered as A36, A992 or A572 Grade 50.

Member lengths of up to 80 ft can be rolled. One feature to note is a heel radius slightly larger than ½ in. on the 12-in. angles, whereas the heel radii on

F_y(ksi) = 50

Shape	W14x				W21x					
lb/ft	873[h]		808[h]		275[h]		248		223	
Design	P_n/Ω_c ASD	$\phi_c P_n$ LRFD	P_n/Ω_c ASD	$\phi_c P_n$ LRFD	P_n/Ω_c ASD	$\phi_c P_n$ LRFD	P_n/Ω_c ASD	$\phi_c P_n$ LRFD	P_n/Ω_c ASD	$\phi_c P_n$ LRFD
Effective length, KL (ft), with respect to least radius of gyration, r_z: 0	7690	11600	7130	10700	2430	3650	2190	3290	1970	2960
11	7300	11000	6750	10100	2130	3200	1920	2880	1720	2580
12	7220	10900	6680	10000	2080	3120	1870	2810	1670	2520
13	7140	10700	6600	9920	2020	3040	1820	2730	1630	2450
14	7060	10600	6520	9800	1960	2950	1760	2650	1580	2370
15	6970	10500	6440	9680	1900	2860	1710	2570	1530	2300
16	6880	10300	6350	9540	1840	2760	1650	2480	1480	2220
17	6780	10200	6250	9400	1780	2670	1590	2400	1420	2140
18	6680	10000	6160	9250	1710	2570	1530	2300	1370	2050
19	6570	9870	6050	9100	1640	2470	1470	2210	1310	1970
20	6460	9700	5950	8940	1570	2370	1410	2120	1260	1890
22	6220	9350	5730	8610	1440	2160	1290	1930	1140	1720
24	5980	8980	5490	8260	1300	1960	1160	1750	1030	1550
26	5720	8600	5250	7890	1170	1760	1040	1570	921	1380
28	5460	8200	5000	7520	1040	1560	925	1390	816	1230
30	5190	7790	4750	7130	916	1380	813	1220	714	1070
32	4910	7380	4490	6750	805	1210	715	1070	628	944
34	4630	6970	4230	6350	713	1070	633	951	556	836
36	4360	6550	3970	5970	636	956	565	849	496	746
38	4080	6140	3710	5580	571	858	507	762	445	669
40	3810	5730	3460	5200	515	775	457	687	402	604
42	3550	5340	3210	4830	467	703	415	623	365	548
44	3290	4950	2970	4470	426	640	378	568	332	499
46	3040	4570	2740	4110	390	586	346	520	304	457
48	2800	4200	2510	3780	358	538	318	477	279	419
50	2580	3870	2320	3480	330	496	293	440	257	387
Properties										
A_g, in.^{2}	257		238		81.0		73.1		65.7	
I_x, in.^{4}	18200		16000		7630		6770		6010	
I_y, in.^{4}	6170		5550		790		701		616	
r_y, in.	4.90		4.83		3.12		3.10		3.06	
r_x/r_y	1.72		1.70		3.11		3.11		3.12	
[h] Flange thickness is greater than 2 in. Special requirements may apply per AISC *Specification* Section A3.1c.							ASD		LRFD	
							$\Omega_c = 1.67$		$\phi_c = 0.9$	

Table 2: Available Strength in Axial Compression of Heavy W-shapes, kips

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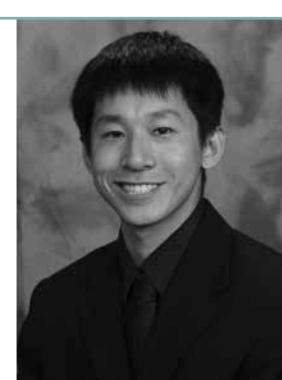


ArcelorMittal

the 10-in. and smaller angles are smaller. The impact of the heel radius on angle cross-sectional properties is minimal and is therefore negligible in design. However, the radius may require additional consideration in welded joint details.

These new shapes are primarily aimed at the transmission line and lattice wind tower market, but will likely be advantageous in other applications as well. Wind load can be reduced by using a single large angle instead of two smaller angles to reduce the total surface exposed, which is particularly useful in wind towers that reach to high altitudes where wind speeds are greater. The large angles allow engineers to more easily design taller towers while using fewer members and connections, which translates to cost savings in material and labor. These principles may reveal new economic solutions in building structures as well.

The dimensions and section properties of the 10-in. and 12-in. angles are provided in Table 3. An axial compression table for the 12-in. angle is shown in Table 4, and the rest of the table for the 10-in. angles can be found at **www.aisc.org/largeWandL**.

Availability

These shapes and all others commonly used in steel construction are listed at **www.aisc.org/availability**. Check out the listings there to learn more about who makes what (not all producers make all of these shapes). Availability should be confirmed by the supplier before use in design. The suppliers can also provide material information, sizes and other technical data.

With the addition of these new larger shapes, engineers now have a more comprehensive toolbox of sections to work with in designing more efficient and economical structures. MSC

▲ Heavy wide-flange.

➤ Table 3: Dimensions and Properties of Large Angles

Shape	k (in.)	Wt. (lb/ft)	A (in.^{2})	Axis X-X					
				I_x (in.^{4})	S_x (in.^{3})	r_x (in.)	$\bar{y}$ (in.)	Z_x (in^3)	y_p (in.)
L12×12×1⅜	2 1/16	105	31.1	415	48.8	3.65	3.50	88.3	1.30
L12×12×1¼	1 15/16	96.4	28.4	383	44.8	3.67	3.46	81.0	1.18
L12×12×1⅛	1 13/16	87.2	25.8	351	40.9	3.69	3.41	73.8	1.08
L12×12×1	1 11/16	77.8	23.0	315	36.5	3.70	3.36	65.9	0.958
L10×10×1⅜	2 1/16	87.1	25.7	234	33.4	3.02	2.99	60.3	1.29
L10×10×1¼	1 15/16	79.9	23.5	216	30.6	3.03	2.95	55.4	1.18
L10×10×1⅛	1 13/16	72.3	21.4	199	28.0	3.05	2.90	50.6	1.07
L10×10×1	1 11/16	64.7	19.1	179	25.0	3.06	2.85	45.3	0.955
L10×10×⅞	1 9/16	56.9	16.8	159	22.1	3.08	2.81	40.0	0.840
L10×10×¾	1 7/16	49.1	14.5	139	19.2	3.09	2.76	34.7	0.725

Shape	Flexural-Torsional Properties			Axis Y-Y						Axis Z-Z				Q_S
	J (in.^{4})	C_w (in.^{6})	r_o (in.)	I_y (in.^{4})	S_y (in.^{3})	r_y (in.)	$\bar{x}$ (in.)	Z_y (in.^{3})	x_p (in.)	I_z (in.^{4})	S_z (in.^{3})	r_z (in.)	tan (α)	F_y=36 ksi
L12×12×1⅜	19.7	209	6.52	415	48.8	3.65	3.50	88.3	1.30	168	33.9	2.32	1.00	1.00
L12×12×1¼	14.9	160	6.56	383	44.8	3.67	3.46	81.0	1.18	154	31.5	2.33	1.00	1.00
L12×12×1⅛	11.1	120	6.59	351	40.9	3.69	3.41	73.8	1.08	141	29.2	2.34	1.00	1.00
L12×12×1	7.80	84.5	6.61	315	36.5	3.70	3.36	65.9	0.958	126	26.5	2.34	1.00	1.00
L10×10×1⅜	16.2	117	5.37	234	33.4	3.02	2.99	60.3	1.29	96.7	22.9	1.94	1.00	1.00
L10×10×1¼	12.3	89.4	5.40	216	30.6	3.03	2.95	55.4	1.18	88.4	21.2	1.94	1.00	1.00
L10×10×1⅛	9.21	67.3	5.43	199	28.0	3.05	2.90	50.6	1.07	81.2	19.8	1.95	1.00	1.00
L10×10×1	6.46	47.6	5.46	179	25.0	3.06	2.85	45.3	0.955	72.4	18.0	1.95	1.00	1.00
L10×10×⅞	4.39	32.5	5.49	159	22.1	3.08	2.81	40.0	0.840	63.8	16.1	1.95	1.00	1.00
L10×10×¾	2.80	20.9	5.53	139	19.2	3.09	2.76	34.7	0.725	55.7	14.3	1.96	1.00	0.983

ArcelorMittal

New 10-in. and 12-in. equal-leg structural angles.

F_y(ksi) = 36

Shape		L12×12x							
		1⅜		1¼		1⅛		1	
lb/ft		105		96.4		87.2		77.8	
Design		ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
Effective length, KL (ft), with respect to least radius of gyration, r_z	0	670	1010	612	920	556	836	496	745
	1	669	1010	611	919	555	835	495	744
	2	667	1000	609	915	553	831	493	741
	3	662	995	605	909	549	826	490	736
	4	655	985	599	900	544	818	485	729
	5	647	973	591	889	537	807	479	720
	6	637	958	582	875	529	795	472	709
	7	626	940	572	859	520	781	463	696
	8	613	921	560	841	509	765	454	682
	9	598	899	547	822	497	747	443	666
	10	582	875	532	800	484	728	432	649
	11	565	850	517	777	470	707	419	630
	12	547	823	501	753	456	685	406	611
	13	528	794	484	727	440	662	392	590
	14	509	765	466	700	424	637	378	568
	15	488	734	447	672	407	612	363	546
	16	467	703	428	644	390	586	348	523
	17	446	671	409	615	373	560	332	499
	18	425	638	389	585	355	534	317	476
	19	403	606	370	556	337	507	301	452
	20	382	574	350	526	320	480	285	428
	21	360	541	331	497	302	454	269	405
	22	339	510	311	468	285	428	254	381
	23	318	478	292	440	267	402	238	358
	24	298	448	274	412	251	377	223	336
	25	278	418	256	384	234	352	209	314
	26	258	388	238	358	218	328	194	292
	27	240	360	221	332	202	304	180	271
	28	223	335	205	309	188	283	168	252
	29	208	312	191	288	175	264	156	235
	30	194	292	179	269	164	246	146	220
	31	182	273	167	252	153	231	137	206
	32	171	256	157	236	144	216	128	193
	33	160	241	148	222	135	204	121	181
	34	151	227	139	209	128	192	114	171
	35	143	214	131	197	120	181	107	161
	36	135	203	124	187	114	171	101	152
	37	128	192	118	177	108	162	96.0	144
	38	121	182	111	168	102	153	91.0	137
Properties									
A_g, in.^{2}		31.1		28.4		25.8		23.0	
r_z, in.		2.32		2.33		2.34		2.34	
						ASD		LRFD	
						$\Omega_c = 1.67$		$\phi_c = 0.9$	

Table 4: Available Strength in Axial Compression of Large Angles

One World Trade Center (scheduled to open late next year), uses some of the new wide-flange shapes.