Larger Hollow Structural Sections

BY JIE ZUO

New larger sizes of square and rectangular HSS offer engineers and architects more opportunities to use these efficient shapes.

THE POPULARITY of hollow structural sections (HSS) in construction has increased dramatically over the years as engineers have become aware of the advantages of HSS and perceived difficulties of designing HSS connections have been addressed. The inclusion of an HSS connection chapter in the AISC *Specification* (Chapter K in ANSI/AISC 360) and design recommendations and aids in the recently published AISC *Steel Design Guide No. 24*, *Hollow Structural Section Connections*, (available as a free download for AISC members at **www.aisc.org/epubs**) have simplified connection design and contributed to the rise in use of HSS.

HSS are very efficient sections and their major benefits are inherent in their shape and engineering properties. Their closed shape and relatively large moment of inertia about the weak axis make them highly resistant against torsional and lateral-torsional effects. They are particularly well suited for axial compression members that have similar unbraced lengths in both directions because of a favorable weak-axis radius of gyration, which often controls the available capacity.

The benefits extend beyond structural considerations to artistic and economic needs as well. Architects can take advantage of the modern and aesthetically pleasing appearance of exposed HSS. In exposed applications, HSS can become an attractive part of the building's visual display, reducing shadows and obscuring spaces.

The unit material cost of HSS is higher than that of open cross sections, but that is not the whole story. The additional strength can permit a lighter design, in some applications. Two examples in *Design Guide 24* compare W-shape and HSS compression members with similar load capacities. For a W8×31, which is 8 in. deep and has an 8-in.-wide flange, the comparable round HSS7.500×0.375 is 8% lighter while HSS8×8×¼ is 17% lighter. Similarly a W14×109 is comparable in size and capacity to the round HSS14.000×0.625 and HSS14×14×½, but for both the HSS is 18% lighter.

Reducing the weight also saves in transportation and erection costs. In those applications where paint or fireproofing is required, the fact that HSS has ⅓ to ½ less surface area than comparable W-shapes can result in using less material and reducing application time, both of which reduce costs. Furthermore, the surfaces are relatively easy to clean and the lack of protruding corners reduces susceptibility to corrosion.

In specialized applications, HSS are extremely versatile and can be used in a variety of applications. Circular hollow sections are especially favorable to resist wind loadings because of their low drag coefficients. The hollow interior can be filled with concrete or other materials to utilize composite action to form a stronger member, as well as increasing its durability under fire conditions.

A recent change to the ASTM A500 standard has increased the maximum periphery of cold-formed HSS from 64 in. to 88 in. and the maximum wall thickness from 0.688 in. to 0.875 in. Taking full advantage of this opportunity, Atlas Tube—the largest HSS producer in North America—is pursuing an agreement with an offshore producer to provide new jumbo-sized A500 HSS. Prior to the introduction of these new shapes, square sections up to 16 in. and 0.625 in. wall thickness were readily available. The jumbo A500 HSS of 18 in., 20 in., and 22 in. square sections and associated rectangles with wall thickness from 0.500 in. to 0.875 in. are expected to be available soon.

Even beyond the opportunities provided by these large A500 shapes, rounds, squares and rectangles outside the

Jie Zuo is a staff engineer with AISC.

Atlas Tube

▲ One of the last steps in producing HSS involves straightening of the walls in a Turk's head, shown here.

Dimensions and Properties for Jumbo Square HSS

Shape	Design Wall Thickness, t	Nominal W_t	Area, A	b/t	h/t	I	S	r	Z	Torsion		Surface Area
										J	C	
	in.	lb/ft	in.^{2}			in.^{4}	in.^{3}	in.	in.^{3}	in.^{4}	in.^{3}	ft^2/ft
HSS22×22×⅞	0.814	244.88	67.3	24.0	24.0	4970	452	8.59	530	7890	729	7.10
×¾	0.698	212.00	58.2	28.5	28.5	4350	395	8.65	462	6860	632	7.13
HSS20×20×⅞	0.814	221.06	60.8	21.6	21.6	3670	367	7.77	433	5870	597	6.43
×¾	0.698	191.58	52.6	25.7	25.7	3230	323	7.84	378	5110	519	6.47
×⅝	0.581	161.40	44.3	31.4	31.4	2750	275	7.88	320	4320	437	6.50
×½	0.465	130.52	35.8	40.0	40.0	2260	226	7.95	261	3510	355	6.53
HSS18×18×⅞	0.814	197.24	54.3	19.1	19.1	2630	292	6.96	346	4220	479	5.77
×¾	0.698	171.16	47.1	22.8	22.8	2320	258	7.02	302	3690	417	5.80
×⅝	0.581	144.39	39.6	28.0	28.0	1980	220	7.07	257	3120	352	5.83
×½	0.465	116.91	32.1	35.7	35.7	1630	181	7.13	210	2540	286	5.87
HSS16×16×⅞	0.814	173.43	47.7	16.7	16.7	1800	225	6.14	268	2920	373	5.10
×¾	0.698	150.75	41.5	19.9	19.9	1590	199	6.19	235	2560	326	5.13
HSS14×14×⅞	0.814	149.61	41.2	14.2	14.2	1170	167	5.33	201	1910	281	4.43
×¾	0.698	130.33	35.9	17.1	17.1	1040	149	5.38	177	1680	246	4.47
HSS12×12×¾	0.698	109.91	30.3	14.2	14.2	631	105	4.56	127	1030	177	3.80
HSS10×10×¾	0.698	89.50	24.7	11.3	11.3	347	69.4	3.75	84.7	578	119	3.13

perimeter limits of A500 also are being made available in the marketplace. They are built up from plates and classified as box sections. The distinction with this line of HSS is not only dimensional—there are differences in material and production techniques as well. The specifier also must evaluate the material because it falls outside the limits of ASTM A500.

Typically, square or rectangular sections within the dimensional limits of A500 are produced with one of two methods. The first involves running a flat steel strip through a progressive set of rollers to continuously cold form the strip into a round cross section. The edges are fused together with a continuous electric resistance seam weld, which does not involve the addition of any filler metal. The resulting tube then is fed into another stand of rollers to precision form the size and shape of the product, either round or rectangular, followed by straightening of the walls in what is called a Turk's head.

Alternatively, for rectangular shapes only, some producers use a second method of production that consists of feeding a flat steel strip through driven forming dies that progressively cold bend the corners of the section. In this method, no bending is performed on the side walls of the section. The square or rectangle is also completed with the electric resistance seam weld process.

In the United States, ASTM A500 Grades B and C material is generally used for cold-formed HSS with yield strengths 46 ksi and 50 ksi, respectively. Other materials, including those with increased atmospheric corrosion resistance, may also be available upon request. There is a ±10% thickness tolerance on the walls that results in the mills consistently producing HSS with thicknesses less than that of nominal. The AISC *Specification* has taken this into account by imposing a 7% reduction in the nominal wall thickness to be used in design.

A third method of production, not involving ASTM A500 or resistance seam welding, also exists wherein box sections are produced by placing two A572 Grade 50 flat steel plates in a brake press to form two identical halves of a complete tube. A backing bar is tack welded to both legs of one of the half sections. Then, the half sections are butted together toe-to-toe and submerged arc welded at the seams to form the complete square or rectangular section. ASTM A1065—a product specification for box sections—permits alternative plate materials and welding processes. While

Dimensions and Properties for Jumbo Rectangular HSS

Shape	Design Wall Thickness, t	Nominal W_t	Area, A	b/t	h/t	Axis X-X				Axis Y-Y				Torsion		Surface Area
						I	S	r	Z	I	S	r	Z	J	C	
	in.	lb/ft	in.^{2}			in.^{4}	in.^{3}	in.	in.^{3}	in.^{4}	in.^{3}	in.	in.^{3}	in.^{4}	in.^{3}	ft^2/ft
HSS24×12×¾	0.698	171.16	47.1	14.2	31.4	3440	287	8.55	359	1170	195	4.98	221	2850	366	5.80
×⅝	0.581	144.39	39.6	17.7	38.3	2940	245	8.62	304	1000	167	5.03	188	2430	310	5.83
×½	0.465	116.91	32.1	22.8	48.6	2420	202	8.68	248	829	138	5.08	154	1980	252	5.87
HSS20×12×¾	0.698	150.75	41.5	14.2	25.7	2190	219	7.26	270	988	165	4.88	190	2220	303	5.13
HSS16×12×¾	0.698	130.33	35.9	14.2	19.9	1270	159	5.95	193	810	135	4.75	158	1610	240	4.47

F_y = 46 ksi
$\phi_c P_n = 0.90 F_{cr} A_g$
$P_n/\Omega_c = F_{cr} A_g / 1.67$

Jumbo Square HSS Shapes
Available Strength in Axial Compression, kips
P_n/Ω_c (ASD), $\phi_c P_n$ (LRFD)

Shape		HSS22x22x				HSS20x20x					
		7/8		3/4		7/8		3/4		5/8	
t_{design}, in		0.814		0.698		0.814		0.698		0.581	
Wt/ft		244		212		221		191		161	
Design		P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$	P_n/Ω_c	$\phi_c P_n$
		ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
Effective length KL (ft) with respect to least radius of gyration r_y	0	1850	2790	1600	2410	1670	2520	1450	2180	1220	1830
	6	1850	2770	1600	2400	1670	2500	1440	2170	1210	1820
	7	1840	2770	1590	2390	1660	2500	1440	2160	1210	1820
	8	1840	2760	1590	2390	1660	2490	1430	2160	1210	1820
	9	1830	2760	1590	2380	1650	2480	1430	2150	1200	1810
	10	1830	2750	1580	2380	1650	2480	1430	2140	1200	1810
	11	1820	2740	1580	2370	1640	2470	1420	2140	1200	1800
	12	1820	2730	1570	2360	1640	2460	1420	2130	1190	1790
	13	1810	2730	1570	2360	1630	2450	1410	2120	1190	1790
	14	1810	2720	1560	2350	1620	2440	1400	2110	1180	1780
	15	1800	2710	1560	2340	1620	2430	1400	2100	1180	1770
	16	1790	2690	1550	2330	1610	2420	1390	2090	1170	1760
	17	1780	2680	1540	2320	1600	2400	1380	2080	1170	1750
	18	1780	2670	1540	2310	1590	2390	1380	2070	1160	1740
	19	1770	2660	1530	2300	1580	2380	1370	2060	1150	1730
	20	1760	2640	1520	2290	1570	2360	1360	2040	1150	1720
	21	1750	2630	1510	2280	1560	2350	1350	2030	1140	1710
	22	1740	2610	1510	2260	1550	2330	1340	2020	1130	1700
	23	1730	2600	1500	2250	1540	2310	1330	2000	1120	1690
	24	1720	2580	1490	2240	1530	2290	1320	1990	1120	1680
	25	1710	2570	1480	2220	1510	2280	1310	1970	1110	1660
	26	1700	2550	1470	2210	1500	2260	1300	1960	1100	1650
	27	1680	2530	1460	2190	1490	2240	1290	1940	1090	1640
	28	1670	2510	1450	2180	1480	2220	1280	1920	1080	1620
	29	1660	2490	1440	2160	1460	2200	1270	1910	1070	1610
	30	1650	2480	1430	2140	1450	2180	1260	1890	1060	1590
	32	1620	2440	1400	2110	1420	2140	1230	1850	1040	1560
	34	1590	2390	1380	2070	1390	2090	1210	1810	1020	1530
	36	1560	2350	1360	2040	1360	2040	1180	1780	1000	1500
	38	1530	2310	1330	2000	1330	2000	1150	1730	974	1460
	40	1500	2260	1300	1960	1300	1950	1130	1690	951	1430
Properties											
A_g (in.^{2})		67.3		58.2		60.8		52.6		44.3	
I_x (in.^{4})		4970		4350		3670		3230		2750	
I_y (in.^{4})		4970		4350		3670		3230		2750	
r_x/r_y		1.00		1.00		1.00		1.00		1.00	
r_y (in.)		8.59		8.65		7.77		7.84		7.88	

[c]Section is slender for axial compression.

◀ Example of the jumbo HSS member selection tables available as downloads.

A1065 includes sections up to 192 in. in periphery and 1 in. in wall thickness, more common sizes range between 64 in. to 120 in. in periphery. The standard weld permits a partial joint penetration groove weld where the groove thickness is at least 80% of the material thickness. Complete joint penetration groove welds can be provided if specified with additional inspection requirements. Consisting of structural plate material, A1065 boxes have a yield strength of 50 ksi, equivalent to that of A500 Grade C HSS. The thickness tolerance of +0.03/-0.01 in. is tighter than that of A500, and the nominal wall thickness reduction of $0.93t_{nom}$ does not apply in design.

Standard Dimensions

With the expansion of the range of HSS sizes comes an opportunity for designers to benefit from a multitude of design possibilities and more efficient structural solutions. Tables showing engineering properties of the jumbo A500 HSS are included here for the use of designers. These tables include the same data as the HSS property tables (Tables 1-11 and 1-12) in the AISC *Steel Construction Manual*. For the purposes of facilitating column design, extensions to *Manual* Tables 4-3 and 4-4 listing available strength in axial compression have also been tabulated for all the new shapes and can be downloaded for free at **www.aisc.org/hss**.

The standard sizes of HSS and box sections produced are available on the Steel Availability page on the AISC website (**www.aisc.org/availability**). Availability of the jumbo A500 HSS should be confirmed by the supplier before use in design. Sizes, engineering properties and other technical data will also be available from the supplier. MSC