

steelwise

ARE YOU PROPERLY SPECIFYING MATERIALS?

BY MARTIN ANDERSON, CHARLES J. CARTER, S.E., P.E., PH.D., AND THOMAS J. SCHLAFLY

Keeping tabs on current ASTM specifications will help you make the right choices when designing and building your projects.

THE MATERIALS AND PRODUCTS used in building design and construction are almost universally designated by reference to an appropriate ASTM specification. This simplifies the design and construction process because you can define all the characteristics of a specified product. However, with dozens of ASTM specifications applicable in steel building construction alone, it can be a challenge to keep the standard designations used in contracts current.

This article provides a summary of the common ASTM specifications used in steel building design and construction, including structural shapes, plate products, fastening products and other products. This information is based upon similar and

more extensive information in the 14th Edition AISC *Steel Construction Manual*. You may also find it convenient to use the AISC publication *Selected ASTM Standards for Steel Construction*, a compilation of more than 60 steel-related ASTM standards. (Both the AISC *Manual* and *Selected ASTM Standards* are available for purchase online at www.aisc.org/bookstore.)

Note that ASTM standards routinely include a section on ordering requirements that lists the variables in each standard that should be specified in a complete order or specification for the material. This is routine for the purchasing department at the local fabrication company and may be of great interest to others as well.

This Article Covers Buildings, but for Bridges...

Another possibility for structural shapes and plates is ASTM A709, which is an “umbrella” standard that assembles ASTM A36, A572, A992, A588 and three high-performance steel (HPS) grades into a convenient single standard for bridge designers and fabricators. The HPS grades are available in plate form only. Grade 50S is available in shapes. The other grades are available in plates form and as shapes, though availability should be confirmed prior to specification.

ASTM A709 provides toughness levels for three exposures and two uses. Much material supplied to A709 meets one of those toughness levels. Material furnished to ASTM A709 grades are acceptable for use where the corresponding parent standard is specified.

STRUCTURAL SHAPES

See Summary in Table 1 (page 18).

W-Shapes

The preferred material specification for W-shapes is ASTM A992 ($F_y = 50$ ksi, $F_u = 65$ ksi). The availability and cost effectiveness of W-shapes in grades other than ASTM A992 should be confirmed prior to their specification. W-shapes with higher yield and tensile strength can be obtained by specifying ASTM A529 Grade 55, ASTM A572 Grades 55, 60 or 65, or ASTM A913 Grades 60, 65 or 70.

W-shapes with atmospheric corrosion resistance (weathering characteristics) can be obtained by specifying ASTM A588 Grade 50. These and other material specifications applicable to W-shapes are shown in Table 1.

Martin Anderson (anderson@aisc.org) is AISC's research and safety project manager. **Charles J. Carter**, S.E., P.E., Ph.D. (carter@aisc.org) is a vice president and chief structural engineer with AISC. **Thomas J. Schlafly** (schlafly@aisc.org) is director of research (and AISC liaison to ASTM, AWS, RCSC and many other industry organizations) with AISC.



Table 1

Table 2-4														
Applicable ASTM Specifications for Various Structural Shapes														
Steel Type	ASTM Designation	F _y Yield Stress ^a (ksi)	F _u Tensile Stress ^a (ksi)	Applicable Shape Series										
				W	M	S	HP	C	MC	L	HSS		Pipe	
											Rect.	Round		
Carbon	A36	36	58-80 ^b											
	A53 Gr B	35	60											
	A500	Gr. B	42	58										
			46	58										
		Gr. C	46	62										
	50		62											
	A501	Gr. A	36	58										
		Gr. B	50	70										
	A529 ^c	Gr. 50	50	65-100										
		Gr. 55	55	70-100										
A709	36	36	58-80 ^b											
A1043 ^d	36	36-52	58											
	50	50-65	65											
High-Strength Low-Alloy	A572	Gr. 42	42	60										
		Gr. 50	50	65										
		Gr. 55	55	70										
		Gr. 60 ^e	60	75										
		Gr. 65 ^e	65	80										
	A618 ^f	Gr. Ia, Ib & II	50 ^g	70 ^g										
		Gr. III	50	65										
	A709	50	50	65										
		50S	50-65	65										
		50W	50	70										
	A913	50	50 ^h	65 ^h										
		60	60	75										
		65	65	80										
		70	70	90										
A992	50 ⁱ	65 ⁱ												
Corrosion Resistant High-Strength Low-Alloy	A588	50	70											
A847	50	70												

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

- a Minimum unless a range is shown.
- b For wide-flange shapes with flange thickness over 3 in., only the minimum of 58 ksi applies.
- c For shapes with a flange or leg thickness less than or equal to 1½ in. only. To improve weldability, a maximum carbon equivalent can be specified (per ASTM Supplementary Requirement S78). If desired, maximum tensile stress of 90 ksi can be specified (per ASTM Supplementary Requirement S79).
- d For shape profiles with a flange width of 6 in. or greater.
- e For shapes with a flange thickness less than or equal to 2 in. only.
- f ASTM A618 can also be specified as corrosion-resistant; see ASTM A618.
- g Minimum applies for walls nominally ¾-in. thick and under. For wall thickness over ¾-in., F_y = 46 ksi and F_u = 67 ksi.
- h If desired, maximum yield stress of 65 ksi and maximum yield-to-tensile strength ratio of 0.85 can be specified (per ASTM Supplementary Requirement S75).
- i A maximum yield-to-tensile ratio of 0.85 and carbon equivalent formula are included as mandatory, and some variation is allowed including for shapes tested with coupons cut from the web; see ASTM A992.



M-Shapes and S-Shapes

The preferred material specification for these shapes is in transition. Use of ASTM A36 ($F_y = 36$ ksi, $F_u = 58$ ksi) is now only slightly more common than use of a 50-ksi grade like ASTM A572 Grade 50, ASTM A529 Grade 50, or ASTM A992; each of these 50-ksi grades has $F_y = 50$ ksi and $F_u = 65$ ksi for these shapes. The availability and cost effectiveness of M-shapes and S-shapes in grades other than these should be confirmed prior to their specification.

M-shapes and S-shapes with a higher yield and tensile strength can be obtained by specifying ASTM A572 Grades 55, 60 and 65, ASTM A529 Grade 55 or ASTM A913 Grades 60, 65 or 70. Atmospheric corrosion resistance (weathering characteristics) can be obtained by specifying ASTM A588 Grade 50. These and other material specifications applicable to M-shapes and S-shapes are shown in Table 1.

Channels

The preceding comments for M-shapes and S-shapes apply equally to channels.

HP-Shapes

The preferred material specification for HP shapes is ASTM A572 Grade 50 ($F_y = 50$ ksi, $F_u = 65$ ksi); the availability and cost effectiveness of other grades should be confirmed prior to specification.

HP-shapes with atmospheric corrosion resistance (weathering characteristics) can be obtained by specifying ASTM A588 Grade 50. These and other material specifications applicable to HP-shapes are shown in Table 1.

Angles

The preceding comments for M-shapes and S-shapes apply equally to angles.

Structural Tees

Structural tees are split from W-, M- and S-shapes to make WT-, MT- and ST-shapes, respectively. For the preferred material specifications, as well as other suitable material specifications for structural tees, refer to the preceding sections on W-, M- or S-shapes, as appropriate.

Rectangular (and Square) HSS

The preferred material specification for rectangular hollow structural sections (HSS) is ASTM A500 Grade C ($F_y = 50$ ksi, $F_u = 62$ ksi). Note that a new standard, ASTM A1085 (see sidebar “New (and Recently New) Things”), seeks to replace it. The availability and cost effectiveness of rectangular HSS in grades other than ASTM A500 Grade C should be confirmed prior to their specification.

Rectangular HSS with atmospheric resistance (weathering characteristics) can be obtained by specifying ASTM A847. These and other material specifications applicable to rectangular HSS are shown in Table 1.

Round HSS

The preferred material specification for round HSS is ASTM A500 Grade C ($F_y = 46$ ksi, $F_u = 62$ ksi). Note that a new standard, ASTM A1085 (see sidebar “New (and Recently New) Things”), seeks to replace it. The availability and cost effectiveness of round HSS in grades other than ASTM A500 Grade C should be confirmed prior to specification.

Generally speaking, only round HSS with the same cross-sectional dimensions as steel pipe are stocked and available. See the sidebar “12 Tidbits” for further information.

Round HSS with atmospheric corrosion resistance (weathering characteristics) can be obtained by specifying ASTM A847. These and other material specifications applicable to round HSS are shown in Table 1.



New (and Recently New) Things

- ▶ *A Channel Especially for Stair Stringers:* The MC12x14.3 that recently was added to ASTM A6 was conceived as a stair stringer. It has a 2 $\frac{1}{8}$ -in. flange width, which is wide enough to accept the common handrail pipe size and fillet weld around it. No more crimping the pipe or goobering the weld!
- ▶ *Bigger HP-shapes:* The HP18- and HP16-series shapes that recently were added to ASTM A6 provide for even higher pile strengths. They, like all HP shapes, also have thicker webs ($t_w = t_p$) and may help eliminate the need for stiffeners and doublers when used as columns.
- ▶ *Larger HSS:* Until recently ASTM A500 HSS was limited to $\frac{5}{8}$ -in. thickness and 64-in. perimeter. It now permits HSS to $\frac{7}{8}$ -in. thickness and 88-in. perimeter. While the standards permit these larger sizes, they are not currently made in the U.S.; availability should be checked. HSS with sizes that exceed ASTM A500's 88-in. periphery limit can also be obtained and are discussed in an article titled "Larger Hollow Structural Sections" in the November 2011 issue of *Modern Steel*. This includes a discussion of ASTM A1065, which covers these shapes produced by forming two channels and welding the channels together.
- ▶ *ASTM A1085 for HSS:* Formalized in April 2013, this new standard offers tighter tolerances on wall thickness and corner radii, shape perimeters of up to 88 inches, minimum yield strength of 50 ksi, minimum tensile strength of 70 ksi and a maximum yield of 70ksi, standard CVN of 25 ft-lb at 40 °F with the option to request a custom CVN through a supplementary requirement. For additional information on ASTM A1085, see www.aisc.org/A1085 and "Hollow Product, Solid Benefit" in the September 2013 issue of *Modern Steel*.
- ▶ *Simpler Bolting:* ASTM recently approved ASTM F3125, an umbrella specification that covers what is now in ASTM A325, A490, F1852 and F2280. The beauty of this standard is that these previously separate standards have been unified, coordinated and made consistent with each other (kudos to Chad Larson, president of LeJeune Bolt Company, for leading the effort to create this significant improvement). In future editions of RCSC and AISC standards, we expect you will see ASTM F3125 referenced instead of the currently separate list of standards. The names of the current standards are used as the names of the grades in the new standard, so you will still be able to order A325, A490, F1852 and F2280 bolts, and you will still be able to identify them by the marks on the head. Stay tuned!
- ▶ *Two other materials to mention:* ASTM A283 covers low-yield carbon steel plate material in four grades. ASTM A1043 covers plates and shapes and is most commonly used as core material in the manufacture of buckling-restrained braces. These two newer products are shown in Tables 1 and 2.
- ▶ *Very High Strength Bolting:* ASTM also just approved ASTM F3111 and F3043, which are 200-ksi structural bolts available in heavy hex and TC versions, respectively. These bolts have strict environmental requirements that are discussed in the standards, but essentially they must always remain dry and free from contact with corrosive chemicals. These bolts are proprietary and not produced domestically ask the steel fabricator to make sure you can obtain these bolts; if so, they may be helpful, especially in large connections.

Steel Pipe

The material specification for steel pipe used in structural frames is ASTM A53 Grade B ($F_y = 35$ ksi, $F_u = 60$ ksi). In some regions, ASTM A53 material is more readily available than ASTM A500 for round cross sections. See the sidebar "12 Tidbits" for further information.

PLATE PRODUCTS

See Summary in Table 2.

Structural Plates

The preferred material specification for structural plates is in transition. Use of ASTM A36 ($F_y = 36$ ksi for plate thickness equal to or less than 8 in., $F_y = 32$ ksi otherwise; $F_u = 58$ ksi) is as common as use of ASTM A572 Grade 50 ($F_y = 50$ ksi, $F_u = 65$ ksi for plate thickness equal to or less than 4 in.). The availability and cost effectiveness of structural plates in grades other than these should be confirmed prior to their specification. Note also the thickness ranges are different for other grades as shown in Table 2-2.

Structural plates with higher yield and tensile strength can be obtained by specifying ASTM A572 Grade 55, 60 or 65, ASTM A529 Grade 55, ASTM A514 Grade 90 or 100 or ASTM A852. Structural plates with atmospheric corrosion resistance (weathering characteristics) can be obtained by specifying ASTM A588 Grade 42, 46 or 50. These and other material specifications applicable to structural plates are shown in Table 2.

Structural Bars

The preceding comments for structural plates apply equally to structural bars, except ASTM A514 is not applicable.

Raised-Pattern Floor Plates

ASTM A786 is the standard specification for rolled steel floor plates. As floor-plate design is seldom controlled by strength considerations, ASTM A786 "commercial grade" is commonly specified. If so, per ASTM A786 Section 5.1.3, "the product will be supplied with 0.33 percent maximum carbon...and without specified

Table 2

Table 2-5															
Applicable ASTM Specifications for Plates and Bars															
Steel Type	ASTM Designation		F _y Yield Stress ^a (ksi)	F _u Tensile Stress ^a (ksi)	Plates and Bars, in.										
					to 0.75 incl.	over 0.75 to 1.25 incl.	over 1.25 to 1.5 incl.	over 1.5 to 2 incl.	over 2 to 2.5 incl.	over 2.5 to 4 incl.	over 4 to 5 incl.	over 5 to 6 incl.	over 6 to 8 incl.	over 8	
Carbon	A36		32	58-80											
			36	58-80											
	A283	Gr. C	30	55-75					d						
		Gr. D	33	60-80					d						
	A529	Gr. 50	50	70-100		b	b	b	b	b					
		Gr. 55	55	70-100		c	c	c	c	c					
A709	Gr. 36	36	58-80												
High-Strength Low-Alloy	A572	Gr. 42	42	60											
		Gr. 50	50	65											
		Gr. 55	55	70											
		Gr. 60	60	75											
	A709	Gr. 50	50	65											
		A1043	Gr. 36	36-52	58										
	Gr. 50		50-65	65											
Corrosion Resistant High-Strength Low-Alloy	A242		42	63											
			46	67											
			50	70											
	A588		42	63											
			46	67											
50			70												
Quenched and Tempered Alloy	A514		90	100-130											
			100	110-130											
Corrosion Resistant Quenched and Tempered Low-Alloy	A709	Gr. 50W	50	70											
		Gr. HPS 50W	50	70											
		Gr. HPS 70W	70	85-110											
		Gr. HPS 100W	90	100-130											
			100	110-130											

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

- a Minimum unless a range is shown.
- b Applicable for plates to 1-inch thickness and bars to 3½-inch thickness.
- c Applicable for plates to 1-inch thickness and bars to 3-inch thickness.
- d Thickness is not limited to 2 in. in ASTM A283 and thicker plates may be obtained but availability should be confirmed.

mechanical properties.” Alternatively, if a defined strength level is desired, ASTM A786 raised-pattern floor plate can be ordered to a specific plate material specification, such as ASTM A36, A572 or A588; see ASTM A786 Sections 5.1.3, and Section 7.

Sheet and Strip

Sheet and strip products, which generally are thinner than structural plate and bar products, are produced to such ASTM specifications as A606, A1008 or A1011. These are “umbrella” standards with many types and grades; the structural steel type is designated “SS” and the standards provide for grades from 25 or 30 to 80. Availability should be checked before specifying the grade.

FASTENING PRODUCTS

See Summary in Table 3.

Conventional Bolts

The preferred material specification for conventional (heavy hex) high-strength bolts in steel-to-steel connections is ASTM A325, although ASTM A490 is equally available and can be specified when higher strength is desired. In either case, Type 1 is the most commonly specified (medium-carbon steel). When atmospheric corrosion resistance is desired, Type 3 can be specified. While still formally permitted in the AISC *Specification*, the use of other material specifications in steel-to-steel bolting applications has become quite uncommon.

Twist-Off-Type Tension-Control Bolt Assemblies

There are two preferred material specifications for twist-off-type tension-control bolt assemblies; ASTM F1852, which offers a strength equivalent to that of ASTM A325 bolts, and ASTM F2280, which offers a strength equivalent to that of ASTM A490 bolts.

Nuts

The preferred material specification for heavy-hex nuts is ASTM A563. The appropriate grade and finish is specified per ASTM A563 Table X1.1 according to the bolt or threaded part with which the nut will be used. For steel-to-steel structural bolting applications, the appropriate grade and finish is summarized in Section 2.4 of the RCSC *Specification*. If its availability can be confirmed prior to specification, ASTM A194 Grade 2H nuts are permitted as an alternative, as indicated in Table 2.1 in the RCSC *Specification*.

Washers for Structural Bolts

The preferred material specification for hardened steel washers is ASTM F436. This specification provides for both flat and beveled washers. Recently, an “extra thick” option was added to provide for the cases in RCSC *Specification* Table 6.1 that require a special $\frac{5}{16}$ -in. thickness (when oversized or slotted holes are used in the outer ply of a steel-to-steel structural joint).

Washers for Anchor Rods

In anchor rod and other embedment applications, hole sizes generally are larger than those for steel-to-steel structural bolting applications; see Table 14-2 in the AISC *Steel Construction Manual*. Accordingly, washers used in such applications generally are larger and might require design consideration for proper force transfer, particularly when the anchorage is subject to tension. Such anchor-rod washers generally are made from plate or bar material. When anchor rods are used in holes that are smaller ($\frac{5}{16}$ -in. larger than rod diameters up to 1 in.; $\frac{1}{2}$ -in. larger than rod diameters over 1 in. to 2 in.; and 1 in. larger than rod diameters over 2 in.) ASTM F844 washers can be used. Note that they can be ordered with a larger diameter than ASTM F436 washers.

Compressible-Washer-Type Direct-Tension Indicators

When bolted joints are specified as pretensioned or slip-critical and the direct-tension-indicator pretensioning method is used, ASTM F959 compressible-washer-type direct-tension indicators are specified. Type 325 is used with ASTM A325 high-strength bolts and type 490 is used with ASTM A490 high-strength bolts. The use of these devices must conform to the requirements in the RCSC *Specification*, which provides detailed requirements for pre-installation verification (Section 7), installation (Section 8) and inspection (Section 9). The RCSC *Specification* also permits alternative washer-type indicating devices subject to the provision in Section 2.6.2.

Anchor Rods

The preferred material specification for anchor rods is ASTM F1554, which covers hooked, headed, threaded and nutted anchor rods in three strength grades: 36, 55 and 105. ASTM F1554 Grade 55 is most commonly specified, although grades 36 and 105 are normally available. Note that, per Section 4.1 in ASTM F1554, when grade 36 is ordered the supplier may substitute weldable grade 55 at their option.

ASTM F1554 Grade 36 may be welded, while Grade 55 may be welded if it is ordered with Supplement S1. Grade 105 may not be welded, as the heat will detrimentally affect performance.

Several other ASTM specifications also may be used. For applications involving rods that are not headed, ASTM A36, A193, A307, A354, A449, A572, A588 and A687 can be specified; note that the ASTM A307 Grade C “anchor bolt” has been deleted from ASTM A307 and replaced by ASTM F1554 Grade 36. For applications involving headed rods, A354 and A449 can be specified.

Threaded Rods

The preferred material specification for threaded rods, whether provided with plain or upset ends, is ASTM A36. Other material specifications that can be specified include ASTM A193, A307, A354, A449, A572, A588 and A687. Note that ASTM A354 Grade BC and A449 are permitted to be used for bolts when the size required is outside the range of ASTM A325.

Table 3

Table 2-6 Applicable ASTM Specifications for Various Types of Structural Fasteners															
ASTM Designation	F _y Yield Stress ^a (ksi)	F _u Tensile Stress ^a (ksi)	Diameter Range (in.)	Bolts			Nuts	Washers			Threaded Rods	Anchor Rods			
				High Strength		Common		Hardened	Plain	Direct-Tension Indicator		Hooked	Headed	Threaded & NUTTED	
				Conventional	Twist-Off-Type Tension Control										
A325	Type 1	–	105	1.125 to 1.5, incl.											
		–	120	0.5 to 1, incl.											
	Type 3	–	105	1.125 to 1.5, incl.											
		–	120	0.5 to 1, incl.											
A490	Type 1	–	150	0.5 to 1.5											
	Type 3	–	150	0.5 to 1.5											
F1852	Type 1	–	105	1.125											
		–	120	0.5 to 1, incl.											
	Type 3	–	105	1.125											
		–	120	0.5 to 1, incl.											
F2280	Type 1	–	150	0.5 to 1.125											
	Type 3	–	150	0.5 to 1.125											
A194 Gr. 2H	–	–	0.25 to 4												
A563	–	–	0.25 to 4												
F436	–	–	0.25 to 4 ^b												
F844	–	–	any												
F959	–	–	0.5 to 1.5												
A36	36	58-80	to 10												
A193 Gr. B7	75	100	over 4 to 7												
	95	115	over 2.5 to 4												
	105	125	2.5 and under												
A307 Gr. A	–	60	0.25 to 4												
A354	Gr. BC	109	125	0.25 to 2.5, incl.											
		99	115	over 2.5 to 4, incl.											
	Gr. BD	115	140	2.5 to 4 incl.											
		130	150	0.25 to 2.5, incl.											
A449	Type 1	58	90	over 1.5 to 3 incl.											
		81	105	over 1 to 1.5 incl.											
	Type 3	92	120	0.25 to 1 incl.											
A572	Gr. 42	42	60	to 6											
	Gr. 50	50	65	to 4 ^c											
	Gr. 55	55	70	to 2											
	Gr. 60	60	75	to 3.5											
	Gr. 65	65	80	to 1.25											
A588	42	63	over 5 to 8, incl.												
	46	67	over 4 to 5, incl.												
	50	70	4 and under												
F1554	Gr. 36	36	58-80	0.25 to 4											
	Gr. 55	55	75-95	0.25 to 4											
	Gr. 105	105	125-150	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.

- Indicates that a value is not specified in the material specification.
- a Minimum unless a range is shown or maximum (max.) is indicated.
- b Diameter range is ½ in. to 1½ in. for beveled and extra thick washers.
- c ASTM A572 permits larger rod diameters, but practicality of threading should be confirmed before specification.



12 Important Tidbits for 2015

1. When in doubt, check it out. Have questions about availability? Call a fabricator or contact the AISC Steel Solutions Center (solutions@aisc.org; 866.ASK.AISC). Either one can keep you swimming in available steel. Also visit www.aisc.org/availability.
2. Times change. ASTM A992 originally was introduced covering only W-shapes. A later revision to this ASTM standard expanded its scope to include other hot-rolled structural cross sections (channels, angles, M-shapes, etc.), allowing them to be made to ASTM A992. Nevertheless, A992 still is not common in shapes other than W-shapes.
3. Round HSS \neq steel pipe. Know the difference between ASTM A500 and ASTM A53. ASTM A500 is for HSS ($F_y = 46$ ksi for Grade C, 42 ksi for Grade B). ASTM A53 is for steel pipe ($F_y = 35$ ksi).
4. Round HSS are similar to steel pipe. Know the similarity between available round HSS (ASTM A500) and steel pipe (ASTM A53). Generally speaking, only round HSS with the same cross-sectional dimensions as steel pipe are stocked and available. So, avoid specifying a round HSS with a cross section that does not match up to one of the steel pipe cross sections. This is a lot easier than it sounds; just use round HSS with non-zero numbers after the decimal point. For example, HSS5.563x0.258 has the same cross-section as a Pipe 5 Std. And it will generally be available, while HSS5.000x0.250 is an HSS-only product and will require a mill-order quantity to obtain.
5. Properly designate your HSS. A round HSS is designated by nominal diameter and wall thickness, each expressed to three decimal places—for example, HSS5.563x0.258. A square or rectangular HSS is designated by nominal outside dimensions and wall thickness, each in rational numbers—for example, HSS5x3x $\frac{3}{8}$.
6. Properly designate your steel pipes. Use nominal pipe size (NPS) designation through NPS 12—for example, Pipe 5 Std., Pipe 5 x-strong or Pipe 5 xx-strong. Note that this notation has commonly been abbreviated as follows for the examples given: P5, PX5 and PXX5 respectively. Above NPS 12, use the format "Pipe" followed by nominal diameter \times nominal wall thickness, each expressed to three decimal places—for example, NPS 14 Standard is designated Pipe 14.000x0.375. The latter format also applies to any steel pipe size smaller than NPS 12 that does not have an NPS size.
7. Don't confuse anchor rods with structural bolts. Do not specify your anchor rods as ASTM A325 or A490. The ASTM A325 and A490 standards cover headed bolts, with limited thread length, generally available only up to 8 in. in length, and governed by provisions for steel-to-steel structural joints only. You say you've always specified your anchorage devices this way and it's never been a problem? Well, the reality is that your fabricator has been awfully nice to not embarrass you by pointing out that you've specified a product that does not come in the length you likely specified—or as a hooked or longer-threaded rod. Use ASTM F1554, which covers hooked, headed and threaded/nutted rods in three strength grades.
8. Have all the information at your fingertips. More extensive information can be found in the 14th Edition AISC *Steel Construction Manual* and the AISC publication *Selected ASTM Standards for Steel Construction*, which are available at www.aisc.org/bookstore.
9. Remember to specify the alternate core location CVN requirement when you have heavy shapes or plates with CJP groove welds and subject to tension; see AISC *Specification* Sections A3.1c and A3.1d for further information.
10. When specifying weathering steel, think ASTM A588 first. ASTM A242 is increasingly less common.
11. Use the MC12x14.3 for stair stringers. The handrail pipe sizes will fit—as will the fillet welds used to connect them on this new channel with a wider flange.
12. When in doubt, check it out and ask your fabricator. Oh wait, this is number 1. Well, it is important.



ASTM A354 Grade BD is permitted when the size required is outside the range of ASTM A490. These standards are material standards, not bolt standards, so the desired dimensions have to be specified as per ANSI ASME B18.2.6 heavy hex class 2A.

Shear Stud Connectors

Shear studs are specified as given in AWS D1.1 Clause 7, with material as required in Clause 7.2.6. Type B is usual and the corresponding mechanical requirements are stated in AWS D1.1 Table 7.1 ($F_y = 51$ ksi, $F_u = 65$ ksi).

Forged Steel Structural Hardware

Forged steel structural hardware products, such as clevises, turnbuckles, eye nuts and sleeve nuts are occasionally used in building design and construction. These products are generally provided to AISI material specifications. AISI C-1035 is commonly used in the manufacture of clevises and turnbuckles. AISI C-1030 is commonly used in the manufacture of steel eye nuts and steel eye bolts. AISI C-1018 Grade 2 is commonly used in the manufacture of sleeve nuts. Other products, such as steel rod ends, steel yoke ends and pins, cotter pins and coupling nuts are provided generically as “carbon steel.” The dimensional and strength characteristics of these devices are described in the literature provided by their manufacturer. Note that such information may be provided as a safe working load and based upon a factor of safety as high as 5, assuming that the product will be used in rigging or similar applications subject to dynamic loading. If so, the tabular value might be overly conservative for permanent installations and similar applications subject to static loading only. In these applications, a factor of safety of 3 is more common.

Filler Metal

Filler metals permitted for use with prequalified welding procedure specifications are shown associated with the base metals for which they are considered “matching” in AWS D1.1 Table 3.1. A tensile strength of 70 is considered matching for base metals up to 70 ksi minimum tensile strength.



OTHER PRODUCTS

Steel Castings and Forgings

Steel castings can be produced in a wide variety of chemical compositions and mechanical properties; most are heat treated. Two standards useful in steel structures are ASTM A216 Grade WCB with Supplementary Requirement S11 and A958A958M Grade SC8620 class 80/50. Steel forgings are specified as ASTM A668.

Crane Rails

Crane rails are furnished to ASTM A759, ASTM A1 and/or manufacturer’s specifications and tolerances. Rail is designated by unit weight in units of pounds per yard. Dimensions of common rail are shown in the AISC 14th Edition *Manual* Table 1-21; other rail profiles also exist and may be available.

Most manufacturers chamfer the top and sides of the crane rail head at the ends unless specified otherwise to reduce chipping of the running surfaces. Often crane rails are ordered as end-hardened, which improves the crane rail ends’ resistance to impact from contact with the moving wheel during crane operation. Alternatively, the entire rail can be ordered as heat-treated. When maximum wheel loading or controlled cooling is needed, refer to manufacturer catalogs. Purchase orders for crane rails should be noted “for crane service.”

Light 40-lb rails are available in 30-ft lengths, standard rails in 33-ft or 39-ft lengths, and crane rails up to 80 ft. Consult manufacturer for availability of other lengths.

Rails should be arranged so that joints on opposite sides of the crane runway will be staggered with respect to each other and with due consideration to the wheelbase of the crane. Rail joints should not occur at crane girder splices. Odd lengths that must be included to complete a run or obtain the necessary stagger should be not less than 10 ft long. Rails are furnished with standard drilling for splice bars in both standard and odd lengths unless stipulated otherwise on the order. ■

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 in. ²	Depth, d in.	Web		Flange		Distance					
			Thickness, t _w in.	t _w /2 in.	Width, b _f in.	Thickness, t _f in.	k		k ₁ in.	T in.	Workable Gage in.	
							k _{des} in.	k _{det} in.				
W14×873	257	23.6	3.94	1.97	18.8	5.51	6.11	6¾	3⅜	10⅞	3-7½-3	
W14×808	238	22.8	3.74	1.87	18.6	5.12	5.72	6⅝	3⅜	10⅞	3-7½-3	
W21×275	81.0	24.1	1.22	0.610	12.9	2.20	2.70	3⅞	17/16	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	2⅞	1⅜	18	5½	
W36×925	272	43.1	3.02	1.51	18.6	4.53	5.48	5¾	21¼/16	31½	7½	
W36×853	251	43.1	2.52	1.26	18.2	4.53	5.48	5¾	27/16	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	5⅞	2¼	31½	7½	
W40×655	193	43.6	1.97	0.985	16.9	3.54	4.72	4¾	2¾/16	34	7½	

Properties														
Shape	Compact Section Criteria		Axis X-X				Axis Y-Y				r _{ts} in.	h _o in.	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. 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 W14x873, which has a flange thickness of 5.5 in., and the heaviest section per linear foot: the W36x925. 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 W14x873 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 1 3/8 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 1/2 in. on the 12-in. angles, whereas the heel radii on

$$F_y(\text{ksi}) = 50$$

Shape	W14x				W21x						
	873 ^h		808 ^h		275 ^h		248		223		
	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	$\phi_c P_n$	
Design	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	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_{gr} , in. ²	257		238		81.0		73.1		65.7		
I_{x_r} , in. ⁴	18200		16000		7630		6770		6010		
I_{y_r} , in. ⁴	6170		5550		790		701		616		
r_{y_r} , in.	4.90		4.83		3.12		3.10		3.06		
r_{x_r}/r_{y_r}	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

Jie Zuo is a staff engineer with AISC. He can be reached at zuo@aisc.org.





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>I_x</i> (in. ⁴)	<i>S_x</i> (in. ³)	<i>r_x</i> (in.)	\bar{y} (in.)	<i>Z_x</i> (in. ³)	<i>y_p</i> (in.)
L12×12×1 ³ / ₈	2 ¹ / ₁₆	105	31.1	415	48.8	3.65	3.50	88.3	1.30
L12×12×1 ¹ / ₄	1 ¹⁵ / ₁₆	96.4	28.4	383	44.8	3.67	3.46	81.0	1.18
L12×12×1 ¹ / ₈	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
L10×10×1 ³ / ₈	2 ¹ / ₁₆	87.1	25.7	234	33.4	3.02	2.99	60.3	1.29
L10×10×1 ¹ / ₄	1 ¹⁵ / ₁₆	79.9	23.5	216	30.6	3.03	2.95	55.4	1.18
L10×10×1 ¹ / ₈	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× ⁷ / ₈	1 ⁹ / ₁₆	56.9	16.8	159	22.1	3.08	2.81	40.0	0.840
L10×10× ³ / ₄	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				<i>Q_S</i>
	<i>J</i> (in. ⁴)	<i>C_w</i> (in. ⁶)	<i>r_o</i> (in.)	<i>I_y</i> (in. ⁴)	<i>S_y</i> (in. ³)	<i>r_y</i> (in.)	\bar{x} (in.)	<i>Z_y</i> (in. ³)	<i>x_p</i> (in.)	<i>I_z</i> (in. ⁴)	<i>S_z</i> (in. ³)	<i>r_z</i> (in.)	tan (α)	
L12×12×1 ³ / ₈	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
L12×12×1 ¹ / ₄	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
L12×12×1 ¹ / ₈	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
L10×10×1 ³ / ₈	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
L10×10×1 ¹ / ₄	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
L10×10×1 ¹ / ₈	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× ⁷ / ₈	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× ³ / ₄	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



$F_y(\text{ksi}) = 36$

Shape	L12x12x							
	1 3/8		1 1/4		1 1/8		1	
lb/ft	105		96.4		87.2		77.8	
Design	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
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								
$A_g, \text{in.}^2$	31.1		28.4		25.8		23.0	
$r_z, \text{in.}$	2.32		2.33		2.34		2.34	
					ASD		LRFD	
					$\Omega_c = 1.67$		$\phi_c = 0.9$	

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



steelwise

HOLLOW PRODUCT, SOLID BENEFIT

BY ERIKA WINTERS-DOWNEY, S.E.,
JIE ZUO AND MENG WANG

A new standard for HSS.

THIS PAST APRIL, ASTM International published a new material standard for the production of hollow structural sections (HSS).

The specification, ASTM A1085-13, is the culmination of six-plus years of work by the AISC HSS Marketing Committee, and the impetus for its creation was a list of desired improvements to the requirements in ASTM A500—e.g., designers have long asked for an elimination of the wall thickness reduction factor required for ASTM A500 to allow for simpler design calculations, as well as suitability for use in fatigue applications and better control of F_y and F_u for seismic overstrength. ASTM A1085 delivers on these wishes and more and contains several differences from ASTM A500.

Tighter Material Tolerances

For starters, ASTM A500 permits wall thickness to be as much as 10% less than the specified nominal thickness compared to a 2.5% variation permitted in wide-flange shapes. To account for this larger variation, AISC *Specification* Section B4.2 requires that the design wall thickness must be taken as 93% of the nominal wall thickness. This affects both member and connection design; the latter can have a significant reduction when the thickness term is squared or cubed.

ASTM A1085 provides two controls on cross section that do not exist or are more lenient in ASTM A500: The wall thickness must be no more than 5% under nominal and the mass must be no more than 3.5% under nominal. In most situations, the latter requirement will ultimately dictate the wall thickness. Regardless, the permitted variation of ASTM 1085 HSS is similar to that for wide-flange shapes. Accordingly, the AISC Committee on Specifications is in the process of developing provisions that we expect will allow the unreduced wall thickness to be used for design of

ASTM 1085 HSS. Citing a 2011 report on HSS wall thickness variations (“Characterizing Dimensional Variability in HSS Members,” prepared for AISC by C.M. Foley and A. Marquez of Marquette University), the task committee responsible for Chapter B has agreed to draft language permitting the use of the nominal wall thickness as the design wall thickness when using A1085.

Additionally:

- ▶ For the first time in an HSS specification, a minimum corner radius for square and rectangular HSS is specified. There are two ranges for acceptable corner radii, depending on the thickness of the shape. The ranges specified will serve to reduce variances outside of normal practice. Radii that are too tight can be susceptible to corner cracking, particularly during the hot-dip galvanizing process. Conversely, when radii are too large, the HSS begins to take on a rounder appearance and may not produce the desired aesthetic effect.
- ▶ ASTM A1085 is applicable for HSS up to an 88-in. periphery and wall thicknesses ranging between 0.148 in. and $\frac{7}{8}$ in. Savvy designers will notice that this precludes the production of material with $\frac{1}{8}$ -in. wall thickness. This limitation is a result of the CVN testing process, which cannot be performed on material thinner than the lower limit.

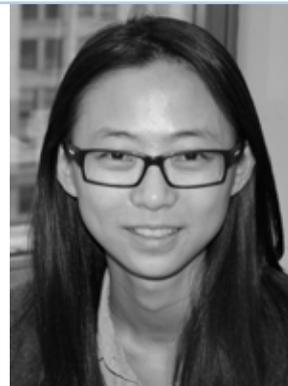
Yield and Tensile Strengths

For simplicity, ASTM A1085, round, square and rectangular HSS are all made in a single grade and all have the same minimum specified yield strength: 50 ksi. The minimum specified tensile strength is 65 ksi. This will simplify calculations because engineers no longer need to select from (or remember!) different yield strengths for varying grades and shapes of HSS.

ASTM A1085 is the only HSS material specification in

Erika Winters-Downey

(wintersdowney@aisc.org) is AISC's Great Plains regional engineer, **Jie Zuo** (zuo@aisc.org) is an AISC staff engineer and **Meng Wang** is an intern in AISC's engineering department.



North America or Europe to place an upper limit on yield strength. All shapes are made with an upper yield strength limit of 70 ksi, which is of benefit in seismic design when the HSS is used as the ductile member.

The coefficients R_y and R_t are used in the AISC *Seismic Provisions* to determine the expected yield and tensile strengths. The available coefficients for other materials are derived from historic production data, which is in the process of being established for ASTM A1085. Data collection is taking place now as this product is now being produced, and the coefficients will be determined.

Standard Charpy V-Notch (CVN) Requirement

ASTM 1085 provides a defined level of material toughness: 25 ft-lbs at 40°F. This corresponds to the AASHTO fracture critical requirements in Zone 2, which encompasses most of the U.S. When a more stringent toughness is required in other zones, the specifier has the option to request a custom CVN value through supplementary requirement.

Material Chemistry

ASTM A1085's material chemistry is slightly different:

- ▶ Copper provisions of A500 were not used in ASTM A1085 to reflect current steel production practices
- ▶ Aluminum content is specified to ensure the steel is killed (oxygen is chemically bound with aluminum to improve steel soundness and facilitate production)
- ▶ Silicon content is limited to improve uniformity of coating when HSS are galvanized
- ▶ A maximum carbon equivalent limit is specified to improve weldability

Using ASTM A1085

With approval of the authority having jurisdiction, ASTM A1085 is being produced and can now be specified. Domestic producers have stated their commitment to producing HSS in ASTM A1085 and making it available; see the producer survey and other online resources available at www.aisc.org/A1085. Steel service centers also are coordinating with producers. Engineers should discuss with their steel fabricators the use of ASTM A1085.

- ▶ Section properties based upon the nominal wall thickness are available. Tables 1-3 show excerpts for square, rectangular and round ASTM A1085 HSS. These tables are modeled after Tables 1-11 through 1-13 in the AISC *Steel Construction Manual*. You will notice that the design wall thickness is equal to the nominal

▼ Table 1: Typical Dimensions and Section Properties for A1085 Square HSS

Shape	Design Wall Thickness, t in.	Nominal Wt lb/ft	Area, A in. ²	b/t	h/t	l in. ⁴	S in. ³	r in.	Z in. ³	Torsion		Surface Area ft ² /ft
										J in. ⁴	C in. ³	
HSS10×10× ³ / ₄	0.750	89.50	26.3	9.73	9.7	364	72.8	3.72	89.4	610	127	3.12
× ⁵ / ₈	0.625	76.33	22.4	12.4	12.4	321	64.2	3.79	77.6	529	109	3.15
× ¹ / ₂	0.500	62.46	18.4	16.4	16.4	271	54.2	3.84	64.6	439	89.8	3.19
× ³ / ₈	0.375	47.90	14.1	23.5	23.5	214	42.8	3.90	50.4	341	69.3	3.23
× ⁵ / ₁₆	0.313	40.35	11.9	28.7	28.7	184	36.8	3.93	42.8	289	58.6	3.24
× ¹ / ₄	0.250	32.63	9.59	36.8	36.8	151	30.2	3.97	34.9	235	47.5	3.26
× ³ / ₁₆	0.188	24.73	7.29	50.0	50.0	116	23.2	3.99	26.7	180	36.2	3.28
HSS9×9× ⁵ / ₈	0.625	67.82	19.9	10.8	10.8	227	50.4	3.38	61.5	377	86.7	2.82
× ¹ / ₂	0.500	55.66	16.4	14.4	14.4	193	42.9	3.43	51.4	315	71.8	2.86
× ³ / ₈	0.375	42.79	12.6	20.8	20.8	154	34.2	3.50	40.3	246	55.6	2.89
× ⁵ / ₁₆	0.313	36.10	10.6	25.6	25.6	132	29.3	3.53	34.3	209	47.1	2.91
× ¹ / ₄	0.250	29.23	8.59	32.8	32.8	109	24.2	3.56	28.0	170	38.2	2.93
× ³ / ₁₆	0.188	22.18	6.54	44.7	44.7	84.0	18.7	3.58	21.5	130	29.2	2.95
HSS8×8× ⁵ / ₈	0.625	59.32	17.4	9.20	9.20	153	38.2	2.97	47.2	258	67.0	2.49
× ¹ / ₂	0.500	48.85	14.4	12.4	12.4	131	32.8	3.02	39.7	217	55.8	2.52
× ³ / ₈	0.375	37.69	11.1	18.1	18.1	106	26.5	3.09	31.3	170	43.4	2.56
× ⁵ / ₁₆	0.313	31.84	9.37	22.4	22.4	91.0	22.8	3.12	26.8	145	36.9	2.58
× ¹ / ₄	0.250	25.82	7.59	28.8	28.8	75.2	18.8	3.15	21.9	118	30.0	2.60
× ³ / ₁₆	0.188	19.63	5.78	39.4	39.4	58.4	14.6	3.18	16.9	90.8	22.9	2.61
HSS7×7× ⁵ / ₈	0.625	50.81	14.9	7.60	7.60	97.6	27.9	2.56	34.8	166	49.9	2.15
× ¹ / ₂	0.500	42.05	12.4	10.4	10.4	84.7	24.2	2.61	29.6	141	41.8	2.19
× ³ / ₈	0.375	32.58	9.58	15.5	15.5	68.7	19.6	2.68	23.5	112	32.7	2.23
× ⁵ / ₁₆	0.313	27.59	8.12	19.2	19.2	59.6	17.0	2.71	20.1	95.7	27.9	2.24
× ¹ / ₄	0.250	22.42	6.59	24.8	24.8	49.4	14.1	2.74	16.5	78.3	22.7	2.26
× ³ / ₁₆	0.188	17.08	5.03	34.0	34.0	38.6	11.0	2.77	12.8	60.3	17.4	2.28

▼ Table 2: Typical Dimensions and Section Properties for A1085 Rectangular HSS

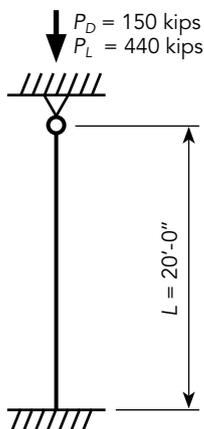
Shape	Design Wall Thickness, t in.	Nominal Wt lb/ft	Area, A in. ²	b/t	h/t	Axis X-X				Axis Y-Y				Torsion		Surface Area ft ² /ft
						l	S	r	Z	l	S	r	Z	J	C	
						in. ⁴	in. ³	in.	in. ³	in. ⁴	in. ³	in.	in. ³	in. ⁴	in. ³	
HSS14×10× ⁵ / ₈	0.625	93.34	27.4	12.4	18.8	728	104	5.15	127	431	86.2	3.97	101	885	156	3.82
× ¹ / ₂	0.500	76.07	22.4	16.4	24.4	608	86.9	5.21	105	361	72.2	4.01	83.6	730	128	3.86
× ³ / ₈	0.375	58.10	17.1	23.5	34.1	476	68.0	5.28	81.5	284	56.8	4.08	64.8	564	98.2	3.89
× ⁵ / ₁₆	0.313	48.86	14.4	28.7	41.5	406	58.0	5.31	69.1	242	48.4	4.10	55.0	478	82.9	3.91
× ¹ / ₄	0.250	39.43	11.6	36.8	52.8	331	47.3	5.34	56.0	198	39.6	4.13	44.6	387	67.0	3.93
HSS14×6× ⁵ / ₈	0.625	76.33	22.4	6.00	18.8	504	72.0	4.74	94.0	130	43.3	2.41	51.2	352	88.9	3.15
× ¹ / ₂	0.500	62.46	18.4	8.40	24.4	426	60.9	4.81	78.3	111	37.0	2.46	42.9	296	73.8	3.19
× ³ / ₈	0.375	47.90	14.1	12.8	34.1	337	48.1	4.89	61.1	89.1	29.7	2.51	33.6	233	57.3	3.23
× ⁵ / ₁₆	0.313	40.35	11.9	16.0	41.5	289	41.3	4.93	51.9	76.9	25.6	2.54	28.7	199	48.6	3.24
× ¹ / ₄	0.250	32.63	9.59	20.8	52.8	237	33.9	4.97	42.3	63.4	21.1	2.57	23.4	162	39.5	3.26
× ³ / ₁₆	0.188	24.73	7.29	28.7	71.3	182	26.0	5.00	32.4	49.2	16.4	2.60	18.0	125	30.2	3.28
HSS14×4× ⁵ / ₈	0.625	67.82	19.9	2.80	18.8	392	56.0	4.44	77.3	49.2	24.6	1.57	30.0	154	55.5	2.82
× ¹ / ₂	0.500	55.66	16.4	4.40	24.4	335	47.9	4.52	64.8	43.1	21.6	1.62	25.5	134	46.8	2.86
× ³ / ₈	0.375	42.79	12.6	7.47	34.1	267	38.1	4.60	50.8	35.4	17.7	1.68	20.3	108	36.8	2.89
× ⁵ / ₁₆	0.313	36.10	10.6	9.58	41.5	230	32.9	4.66	43.4	30.9	15.4	1.71	17.4	93.2	31.5	2.91
× ¹ / ₄	0.250	29.23	8.59	12.8	52.8	189	27.0	4.69	35.4	25.8	12.9	1.73	14.3	77.0	25.7	2.93
× ³ / ₁₆	0.188	22.18	6.54	18.1	71.3	147	21.0	4.74	27.2	20.3	10.2	1.76	11.1	59.8	19.8	2.95
HSS12×10× ¹ / ₂	0.500	69.27	20.4	16.4	20.4	419	69.8	4.53	83.9	316	63.2	3.94	74.1	581	109	3.52
× ³ / ₈	0.375	53.00	15.6	23.5	28.8	330	55.0	4.60	65.2	249	49.8	4.00	57.6	450	83.7	3.56
× ⁵ / ₁₆	0.313	44.60	13.1	28.7	35.1	282	47.0	4.64	55.3	213	42.6	4.03	48.9	381	70.8	3.58
× ¹ / ₄	0.250	36.03	10.6	36.8	44.8	230	38.3	4.66	44.9	174	34.8	4.05	39.7	309	57.2	3.60
HSS12×8× ⁵ / ₈	0.625	76.33	22.4	9.20	15.6	419	69.8	4.32	87.1	221	55.2	3.14	65.6	481	104	3.15
× ¹ / ₂	0.500	62.46	18.4	12.4	20.4	353	58.8	4.38	72.4	188	47.0	3.20	54.7	401	85.8	3.19
× ³ / ₈	0.375	47.90	14.1	18.1	28.8	279	46.5	4.45	56.5	149	37.2	3.25	42.7	312	66.3	3.23
× ⁵ / ₁₆	0.313	40.35	11.9	22.4	35.1	239	39.8	4.48	48.0	128	32.0	3.28	36.4	265	56.1	3.24
× ¹ / ₄	0.250	32.63	9.59	28.8	44.8	196	32.7	4.52	39.1	105	26.2	3.31	29.6	216	45.5	3.26
× ³ / ₁₆	0.188	24.73	7.29	39.4	60.6	151	25.2	4.55	29.9	81.3	20.3	3.34	22.7	165	34.7	3.28

Comparing A1085 to A500

The following is excerpted from a design example of a square HSS compression member without slender elements (see the full example at www.aisc.org/A1085).

Given:

Select an ASTM A1085 square HSS column, with a length of 20 ft, to support a dead load of 150 kips and live load of 440 kips in axial compression. The base is fixed and the top is pinned. Compare it to the size that would be required for an ASTM A500 Grade B square HSS.



Solution:

The required compressive strength is:

► LRFD: $P_u = 884$ kips

► ASD: $P_a = 590$ kips

Summary of results:

HSS Standard	Selected Section	Area (in. ²)	Weight (lb/ft)	Design Strength, ϕP_n (kips)	Allowable Strength, P_n/Ω (kips)
ASTM A1085	HSS12×12× ¹ / ₂	22.4	76.1	891	593
ASTM A500 Gr. B	HSS12×12× ⁵ / ₈	25.7	93.3	946	629

The column size required for ASTM A1085 material is an HSS12×12×¹/₂, which has a design strength of 891 kips and an allowable strength of 593 kips. This same cross section in ASTM A500 Grade B material is not adequate (design strength is 773 kips and allowable strength is 514 kips). Using a ⁵/₈-in. wall thickness, the HSS12×12×⁵/₈ has a design strength of 946 kips and an allowable strength of 629 kips. However, it weighs 17 lbs more per ft.

In this case, using ASTM A1085 allows an 18% reduction in weight. Since fabrication, erection and other costs are likely unaffected, that's a direct savings that likely will more than offset the additional cost of the A1085 material.

wall thickness for ASTM A1085, and this has a direct effect on every property in the table with the exception of the nominal weight, which has always been based upon nominal dimensions.

- ▶ Axial compression strength tables also are available, as illustrated in Table 4, which shows an excerpt of an axial compression table for square A1085 HSS. These tables are modeled after Tables 4-3 through 4-5 in the AISC *Steel Construction Manual*.
- ▶ A design example is provided that compares a column designed with ASTM 1085 material to a column designed with A500 material. The calculations for the design example are omitted in this article, but a summary of the comparison results is shown.

▼ Table 3: Typical Dimensions and Section Properties for A1085 Round HSS

Shape	Design Wall Thickness, t	Nominal Wt	Area, A	D/t	I	S	r	Z	Torsion	
	in.	lb/ft	in. ²		in. ⁴	in. ³	in.	in. ³	J	C
HSS10×0.625	0.625	62.64	18.4	16.0	203	40.6	3.32	55.0	406	80.6
×0.500	0.500	50.78	14.9	20.0	169	33.8	3.36	45.2	338	67.2
×0.375	0.375	38.58	11.3	26.7	132	26.3	3.41	34.8	263	52.5
×0.312	0.312	32.31	9.50	32.1	112	22.3	3.43	29.3	223	44.5
×0.250	0.250	26.06	7.66	40.0	91.1	18.2	3.45	23.8	182	36.4
×0.188	0.188	19.72	5.80	53.2	69.8	14.0	3.47	18.1	140	27.9
HSS9.625×0.500	0.500	48.77	14.3	19.2	150	31.1	3.23	41.7	299	61.9
×0.375	0.375	37.08	10.9	25.7	117	24.3	3.27	32.1	233	48.4
×0.312	0.312	31.06	9.13	30.8	99.1	20.6	3.29	27.1	198	41.1
×0.250	0.250	25.06	7.36	38.5	81.0	16.8	3.32	22.0	162	33.6
×0.188	0.188	18.97	5.57	51.2	62.1	12.9	3.34	16.7	124	25.8
HSS8.625×0.625	0.625	53.45	15.7	13.8	126	29.3	2.84	40.1	253	58.0
×0.500	0.500	43.43	12.8	17.2	106	24.5	2.88	33.0	211	48.7
×0.375	0.375	33.07	9.72	23.0	82.9	19.2	2.92	25.5	166	38.3
×0.322	0.322	28.58	8.40	26.8	72.5	16.8	2.94	22.2	145	33.5
×0.250	0.250	22.38	6.58	34.5	57.7	13.4	2.96	17.5	115	26.7
×0.188	0.188	16.96	4.98	45.9	44.4	10.3	2.98	13.4	88.7	20.6
HSS7.625×0.375	0.375	29.06	8.54	20.3	56.3	14.8	2.57	19.7	113	29.4
×0.328	0.328	25.59	7.52	23.2	50.1	13.2	2.58	17.5	100	26.2

Cost

Any discussion of a new product in the marketplace is not complete without addressing potential cost implications. We expect that ASTM A1085 material will cost more than ASTM A500—but also that the weight savings due to the enhanced material properties will offset some or even all of the added

material cost. And, as always, one should remember that material costs are only about 30% of a typical steel frame, with the rest made up by fabrication, erection and other costs. The largest savings and efficiencies can be achieved from constructability review and early involvement of your steel fabricator. MSC

▼ Table 4: Available Strength in Axial Compression for A1085 Square HSS

F_y = 50 ksi

Shape		HSS22×22×				HSS20×20×						
		7/8		3/4		7/8		3/4		5/8		
t _{design} , in		0.875		0.750		0.875		0.750		0.625		
Wt /ft		244.88		212.00		221.06		191.58		161.40		
Design		P _n / Ω _c		P _n / Ω _c		P _n / Ω _c		P _n / Ω _c		P _n / Ω _c		
		ASD	LRFD									
Effective length KL (ft) with respect to least radius of gyration, r _y	0	2160	3240	1870	2800	1950	2930	1690	2530	1420	2130	
	6	2140	3220	1860	2790	1930	2910	1680	2520	1410	2120	
	7	2140	3220	1850	2780	1930	2900	1670	2510	1410	2120	
	8	2140	3210	1850	2780	1920	2890	1670	2510	1400	2110	
	9	2130	3200	1840	2770	1920	2880	1660	2500	1400	2100	
	10	2120	3190	1840	2760	1910	2870	1660	2490	1400	2100	
	11	2120	3180	1830	2760	1910	2860	1650	2480	1390	2090	
	12	2110	3170	1830	2750	1900	2850	1640	2470	1380	2080	
	13	2100	3160	1820	2740	1890	2840	1640	2460	1380	2070	
	14	2100	3150	1810	2730	1880	2830	1630	2450	1370	2060	
	15	2090	3140	1810	2720	1870	2810	1620	2440	1370	2050	
	16	2080	3120	1800	2700	1860	2800	1610	2420	1360	2040	
	17	2070	3110	1790	2690	1850	2780	1600	2410	1350	2030	
	18	2060	3090	1780	2680	1840	2760	1590	2400	1340	2020	
	19	2050	3080	1770	2660	1830	2750	1580	2380	1330	2010	
	20	2040	3060	1760	2650	1810	2730	1570	2360	1330	1990	
	21	2020	3040	1750	2630	1800	2710	1560	2350	1320	1980	
	22	2010	3020	1740	2620	1790	2690	1550	2330	1310	1960	
	23	2000	3000	1730	2600	1770	2670	1540	2310	1300	1950	
	24	1980	2980	1720	2580	1760	2640	1530	2290	1290	1930	
	25	1970	2960	1710	2570	1740	2620	1510	2270	1280	1920	
	26	1960	2940	1690	2550	1730	2600	1500	2250	1270	1900	
	27	1940	2920	1680	2530	1710	2570	1490	2230	1250	1880	
	28	1930	2890	1670	2510	1700	2550	1470	2210	1240	1870	
	29	1910	2870	1660	2490	1680	2520	1460	2190	1230	1850	
	30	1890	2850	1640	2470	1660	2500	1440	2170	1220	1830	
	32	1860	2800	1610	2420	1630	2440	1410	2120	1190	1790	
	34	1830	2740	1580	2380	1590	2390	1380	2080	1170	1750	
	36	1790	2690	1550	2330	1550	2330	1350	2030	1140	1710	
	38	1750	2630	1520	2280	1510	2270	1310	1970	1110	1670	
	40	1710	2570	1490	2230	1470	2210	1280	1920	1080	1630	
	Properties											
	A _g , in. ²	72.0		62.3		65.0		56.3		47.4		
	I _x = I _y , in. ⁴	5280		4630		3900		3430		2940		
	r _x = r _y , in.	8.56		8.62		7.75		7.81		7.88		
	ASD	LRFD										
	Ω _c = 1.67	φ _c = 0.90										

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



Atlas Tube

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



Jie Zuo is a staff engineer with AISC.

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× $\frac{7}{8}$	0.814	244.88	67.3	24.0	24.0	4970	452	8.59	530	7890	729	7.10
× $\frac{3}{4}$	0.698	212.00	58.2	28.5	28.5	4350	395	8.65	462	6860	632	7.13
HSS20×20× $\frac{7}{8}$	0.814	221.06	60.8	21.6	21.6	3670	367	7.77	433	5870	597	6.43
× $\frac{3}{4}$	0.698	191.58	52.6	25.7	25.7	3230	323	7.84	378	5110	519	6.47
× $\frac{5}{8}$	0.581	161.40	44.3	31.4	31.4	2750	275	7.88	320	4320	437	6.50
× $\frac{1}{2}$	0.465	130.52	35.8	40.0	40.0	2260	226	7.95	261	3510	355	6.53
HSS18×18× $\frac{7}{8}$	0.814	197.24	54.3	19.1	19.1	2630	292	6.96	346	4220	479	5.77
× $\frac{3}{4}$	0.698	171.16	47.1	22.8	22.8	2320	258	7.02	302	3690	417	5.80
× $\frac{5}{8}$	0.581	144.39	39.6	28.0	28.0	1980	220	7.07	257	3120	352	5.83
× $\frac{1}{2}$	0.465	116.91	32.1	35.7	35.7	1630	181	7.13	210	2540	286	5.87
HSS16×16× $\frac{7}{8}$	0.814	173.43	47.7	16.7	16.7	1800	225	6.14	268	2920	373	5.10
× $\frac{3}{4}$	0.698	150.75	41.5	19.9	19.9	1590	199	6.19	235	2560	326	5.13
HSS14×14× $\frac{7}{8}$	0.814	149.61	41.2	14.2	14.2	1170	167	5.33	201	1910	281	4.43
× $\frac{3}{4}$	0.698	130.33	35.9	17.1	17.1	1040	149	5.38	177	1680	246	4.47
HSS12×12× $\frac{3}{4}$	0.698	109.91	30.3	14.2	14.2	631	105	4.56	127	1030	177	3.80
HSS10×10× $\frac{3}{4}$	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 $\pm 10\%$ 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× $\frac{3}{4}$	0.698	171.16	47.1	14.2	31.4	3440	287	8.55	359	1170	195	4.98	221	2850	366	5.80
× $\frac{5}{8}$	0.581	144.39	39.6	17.7	38.3	2940	245	8.62	304	1000	167	5.03	188	2430	310	5.83
× $\frac{1}{2}$	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× $\frac{3}{4}$	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× $\frac{3}{4}$	0.698	130.33	35.9	14.2	19.9	1270	159	5.95	193	810	135	4.75	158	1610	240	4.47

Jumbo Square HSS Shapes Available Strength in Axial Compression, kips P _n /Q _c (ASD), φ _c P _n (LRFD)											
Shape		HSS22x22x				HSS20x20x					
f _{design} , in		7/8		3/4		7/8		3/4		5/8	
Wt/ft		244		212		221		191		161	
Design	Effective length KL (ft) with respect to least radius of gyration r _y	P _n /Q _c		φ _c P _n		P _n /Q _c		φ _c P _n		P _n /Q _c	
		ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD
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		1690	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	

^SSection 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**

Something BOLTED this Way Comes

BY TOBY ANDERSON

The toil of revising the F1554 standard will help reduce the trouble of specifying anchor bolts.

THERE ARE A LOT of memorable scenes from *Macbeth*.

The knife floating through the air, the “Tomorrow and tomorrow and tomorrow” soliloquy and Lady Macbeth trying to scrub her hands clean all come to mind.

For me, the scene with three witches and their bubbling cauldron is the one that stands out the most. And it’s not just because it’s such a great scene, but also because the brew’s disparate and unfamiliar ingredients mimicked the disparate components that came together in a recently completed standard. This past November, colleagues representing bolt suppliers have completed a revision of ASTM F1554-15, *Standard Specification for Anchor Bolts, Steel, 36, 55, and 105 ksi Yield Strength*. The group took into consideration strength, ductility, the effects of heat treatment and cold work, the capabilities of producers and the needs of designers—albeit with fewer poisoned entrails and eyes of newt.

Prior to 1994, designers commonly used other bolt standards to call out anchor rods, because there was no standard written specifically for them. ASTM adopted F1554 that year and AISC soon recommended it for anchor rods, but it has seen only minor revisions since then. As design codes adopted it, engineers and other specifiers designed with it, and suppliers naturally have seen increased requests. However, over the

last few years, designers and producers noticed a few inconsistencies that complicated what ought to be clear requirements. Hearing such concerns, the ASTM-led task group met, drafted and completed an important update to this increasingly vital standard. With the goal in mind of a clear and economical standard that meets engineering requirements, the group made many changes; a few of the important ones are described here.

New Ingredients

First, ACI 318-11 Appendix D design provisions defined ductile anchor rods with multiple parameters: reduction of area (ROA) that varied by grade and diameter and two measures of elongation. Two grades within F1554 straddled the requirements, with some parameters meeting the ductility limits while others did not. This led to designers using the lower resistance factors required for non-ductile materials, a 15% decrease in available strength. The “brittle” designation (vs. “ductile” anchors) may have necessitated additional design considerations, unless users specified higher reduction-of-area requirements than those in F1554. After consulting mills, manufacturers, bolting suppliers and ACI, the task group found that Grade 55 bars in most diameters were certified already to ROAs higher than F1554 required. To avoid the complications of the “brittle” designation, then, stakeholders agreed to raise F1554 Grade 55 ROA requirements to a minimum of 30% for all diameters.

The more recent standard, ACI 318-14, moved the definition of “steel element, ductile” to Section 2.3 (“Terminology”), but kept it essentially the same: “element with a tensile test elongation of at least 14% and reduction in area of at least 30%.”

While the actual term “brittle” is not contained in the ACI 318, one can assume that if an anchor does not meet the definition of “steel element, ductile,” it may be classified as brittle.

Due to ACI 318’s definition, it still is possible, technically, to have a brittle Grade 105 bolt in ASTM F1554. Therefore, if a ductile Grade 105 is required, designers need to modify their contract specifications to require a 14% minimum elongation. (All other F1554 grades are ductile.)



Toby Anderson (baybolt@pacbell.net) is general manager of Bay Bolt.

Second, the original standard did not anticipate the growth of cold-drawn threaded rod (“all-thread”) as an anchoring product, and certain sections allowed such rods’ *pre-drawn* tensile properties to qualify its *finished* tensile properties. Conceivably, a finished Grade 36 all-thread rod—e.g., after it had been drawn and threaded—could have exceeded the standard’s upper limit for ultimate tensile strength, even though its original raw material did not. The task group revised and clarified these sections to make the requirement clear: All tensile properties are to be determined only after all cold-drawing (and heat-treating, if performed) is completed. (What is not new is that Grades 36 and 55 anchor rods in sizes through 1½ in. and Grade 105 rods through 1¼ in., when tested full-size, still need to meet only yield strength and ultimate tensile requirements. ROA and elongation need not be reported for those sizes.)

Next, answering frequent queries, the group clarified that Grade 36 anchors are considered weldable, and to help ensure such weldability for even cold-drawn all-thread (which are often cut into shorter studs for anchoring), they lowered the grade’s maximum carbon content by 0.01% (to 0.25%). In addition, recognizing a current industry process, the members revised the standard to allow all-thread rod manufacturers to perform qualifying tensile tests on coupons that have been drawn to pitch diameter, but not yet threaded. (Tensile properties are then extrapolated from the standard’s full-size test requirements.)

The task group made minor revisions as well. They provided dimensional guidance for hex-head anchors, deleted extraneous metric equivalents, replaced references to “certifications” with “test reports” (the ASTM Fastener Committee’s preferred usage) and consolidated and standardized certain sections (which had no other than mere editorial impact). Finally, the group deleted sizes under ½ in., having found no structural anchoring applications that specify such small diameters.

Ghosts of the Past

In addition to the changes in F1554-15, this is a good place to review some other areas of this specification. Like other ASTM product standards, F1554 includes an “ordering information” section (Section 5) that includes: quantity, product name, ASTM Designation and year, grade and class, copper content, nominal diameter and thread pitch, bolt length, thread length, head type (if required), hook angle and hook length (if required), coatings, number of nuts, number of washers, source inspection requirements, color marking (if different from the standard’s), test reports, supplementary requirements (if required) and special packaging requirements (if required).

Something else that is not new: The actual minimum body diameters are smaller than the nominal diameters, and they are smaller for rolled threads than for cut threads. Designers ought to account for this variance. (See the adjacent table.) AISC and ACI have different ways to design threaded rod and in light of the minimum diameter for F1554, yield on the body of the rod might need to be checked. On the next page is an example using a 2-in.-diameter Gr 105 threaded rod:

F1554 Anchor Rod Minimum Body Diameters ^A				
Nominal Diameter, in.	Threads/in.	Body Diameter, min, in.		
		Rolled Threads ^B		Cut Threads ^C Classes 1A and 2A
		Class1A	Class2A	
Unified Coarse Thread Series (UNC)				
½	13 UNC	0.4411	0.4435	0.4822
5⁄8	11 UNC	0.5561	0.5589	0.6052
¾	10 UNC	0.6744	0.6773	0.7288
7⁄8	9 UNC	0.7914	0.7946	0.8523
1	8 UNC	0.9067	0.9100	0.9755
1 1⁄8	7 UNC	1.0191	1.0228	1.0982
1 ¼	7 UNC	1.1439	1.1476	1.2232
1 ½	6 UNC	1.3772	1.3812	1.4703
1 ¾	5 UNC	1.6040	1.6085	1.7165
2	4 ½ UNC	1.8385	1.8433	1.9641
2 ¼	4 ½ UNC	2.0882	2.0931	2.2141
2 ½	4 UNC	2.3190	2.3241	2.4612
2 ¾	4 UNC	2.5686	2.5739	2.7111
3	4 UNC	2.8183	2.8237	2.9611
3 ¼	4 UNC	3.0680	3.0734	3.2110
3 ½	4 UNC	3.2110	3.3233	3.4610
3 ¾	4 UNC	3.5674	3.5730	3.7109
4	4 UNC	3.8172	3.8229	3.9609
8 Thread Series (8 UN)				
1 1⁄8	8 UN	...	1.0348	1.1004
1 ¼	8 UN	...	1.1597	1.2254
1 ½	8 UN	...	1.4093	1.4753
1 ¾	8 UN	...	1.6590	1.7252
2	8 UN	...	1.9087	1.9752
2 ¼	8 UN	...	2.1584	2.2251
2 ½	8 UN	...	2.4082	2.4751
2 ¾	8 UN	...	2.6580	2.7250
3	8 UN	...	2.9077	2.9749
3 ¼	8 UN	...	3.1575	3.2249
3 ½	8 UN	...	3.4074	3.4749
3 ¾	8 UN	...	3.6571	3.7248
4	8 UN	...	3.9070	3.9748

^A Extracted from ASME B 1.1.

^B Minimum body diameter is the same as minimum pitch diameter.

^C Minimum body diameter is the same as minimum major diameter.

AISC:

Tensile from Table J3.2 $F_{nt} = 0.75 F_u$

$$R_n = F_{nt} A_b = 0.75 (125)(3.14) = 294$$

$$\text{Design Strength} = \phi R_n = 0.75(294) = 221\text{k}$$

ACI:

$$R_n = F_{nt} (A_b) \text{ where } F_{nt} = F_u \text{ and } A_b =$$

$$\text{Net tension area of the threaded bolt} = 125 (2.5) = 312$$

(see *Steel Construction Manual* Table 7-17 for A_b value.)

$$\text{Design strength} = \phi R_n = 0.65(262) = 203\text{k}$$

AISC yield on the body:

$$R_n = F_y A_{min} = 105[(\pi (1.83852/4))] = 278.7$$

$$\text{Design strength} = \phi R_n = 0.90 (278.7) = 250\text{k}$$

During the F1554 revision process, ASTM, AISC and ACI members endeavored to gather many industry voices, realizing that creating and amending product standards is much like creating a forging (though generally at lower temperatures and with less slag). The best standards are clear, concise and forged by groups that have all the information—consumers—mills, manufacturers, distributors, specifiers, and end users—represented, and where each listens, collaborates and contributes their bit to the chemistry (or the hammering).

Writing the Play

This new publication is the result of disparate industry players joining forces to coordinate, unify and rationalize the standard for anchor rods. I encourage all industry members to

join the standards organizations linked to their specialty and to participate in similar collaborative processes, if only to combat the occasional impression that standards are brewed up with dragon scales and wolf teeth and foisted on an industry to create toil and trouble. ■

F1554 Anchor Rod Tensile Properties ^A			
	Grade		
	36	55	105
Tensile strength, ksi	58–80	75–95	125–150
Yield strength, min, ksi (0.2% offset)	36	55	105
Elongation in 2 in., min, % (machined specimens) ^A	23	21	15
Elongation in 8 in., min, % (bar stock) ^A	20	18	12
Reduction of Area, min %	40	30	45

^A Elongation and ROA need not be reported for rods tested full-size.

F1554 Anchor Rod Welding Colors	
Grade	Color
36	Blue
55	Yellow
55- Weldable ^A	Yellow (projecting end) and White (encased end)
105	Red

^A When Supplementary S1 is used.