This month's SteelWise features answers to common questions on mill production and tolerances.

steelwise

A HIGH TOLERANCE FOR ACCURACY

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AISC IS UPDATING the Frequently Asked Questions section of its website (www.aisc.org). As these updates are created, selected sections will be published as SteelWise articles. This month's installment covers mill production and tolerances.

1. Mill Production and Tolerances

ASTM A6/A6M covers mill requirements for structural steel, including dimensional tolerances on the cross section of structural shapes, the quality requirements and the type of mill conditioning permitted. ASTM A500 and A53 have similar requirements for HSS and steel pipe. The FAQs in this section include a discussion of portions of these provisions and the work required either when supplied material does not meet the tolerances specified or when more restrictive tolerances are specified. Note that several ASTM standards are referenced in the discussions. Much of the most commonly used information is also reproduced in Part 1 of the AISC *Steel Construction Manual*.

1.1. Cross-Sectional and Straightness Tolerances

1.1.1. Where are the (mill) dimensional tolerances for structural shapes and plates given?

Permissible variations for structural shapes and plates as received from the mill are established in ASTM A6/A6M Section 12. These historically developed standard tolerances define the acceptable limits of variation from theoretical dimension for the cross-sectional area, flatness, straightness, camber and sweep for rolled sections. It should be noted that cross-sectional tolerances are expressed as a percentage of weight or area, not as tolerances on dimensions such as the flange and web thicknesses.

Generally, standard fabrication practices accommodate these structurally acceptable variations. In special cases, such as high-rise construction, the accumulation of mill tolerances may require consideration in design by the structural engineer of record. If more restrictive tolerances are required, they must be specified in the contract documents.

1.1.2. Where are the dimensional tolerances for HSS and steel pipe given?

ASTM A500 Section 11 and ASTM A53 Section 10 provide this information.

1.2. Surface Condition

1.2.1. Where are the permissible variations in surface condition for structural shapes defined?

ASTM A6/A6M-Section 9 defines the permissible variations in the surface condition for structural shapes and plates in the as-rolled condition. It should be recognized that surface imperfections, such as seams and scabs, within these specified limits may be present on material received at the fabrication shop—particularly on heavyweight sections because of higher finishing temperatures and production difficulties. Certain steel chemistries, such as that for ASTM A588, will also exhibit a higher incidence of surface imperfections.

Special surface condition requirements must be specified in the contract documents. Material purchased to meet the requirements of ASTM A6/A6M is usually subject to acceptance or rejection based upon visual inspection both at the rolling mill and at the time of receipt by the fabricator, although more extensive inspection methods may be used. This inspection is important because mills normally limit their contractual liability to replacement or credit. Because occasional surface imperfections may be discovered after the fabricator's acceptance of mill material, particularly after blast cleaning, any requirements for remedial work should also be specified in the contract documents.

Similar information is provided in ASTM A500/A500M Section 16 for HSS and ASTM A53/53M Section 12 for steel pipe.

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1.2.2. What corrective procedures are available to the mill when variations in surface condition do not meet specified tolerances?

ASTM A6/A6M Section 9 specifies limited conditioning that the mill may perform when as-rolled material does not meet specified tolerances. Note that it further states that "conditioning of imperfections beyond the [specified] limits... may be performed by [the fabricator] at the discretion of [the fabricator]."

Unless required in the contract documents, code-compliant surface imperfections generally need not be repaired or removed if they are not detrimental to the strength of the member. When required, they may be repaired by grinding or welding. The responsibility for any required repairs should be assigned in the contract documents so that it is clearly understood by all parties involved, including the owner's designated representative for construction (usually the general contractor), fabricator, erector and painter.

1.2.3. How should edge discontinuities in mill material be treated?

Non-injurious edge discontinuities in statically loaded structures need not be removed or repaired unless otherwise specified in the contract documents. Injurious defects should be repaired. Repairs may be by grinding and if necessary to restore material, via welding. The provisions of AWS D1.1: Clause 5.15.1.1 for edges that are to be welded are appropriate for non-welded edges, except that:

- Discontinuities need not be explored to a depth greater than 1 in. When the depth of a discontinuity exceeds 1 in., the discontinuity should be gouged out to a depth of 1 in. beyond its intersection with the surface and repaired by the deposition of weld metal as indicated in AWS D1.1: Clause 5.15.1.1.
- For discontinuities over 1 in. long, with depth exceeding ⅛ in. but not greater than 1 in., the discontinuity must be removed and repaired, but no single repair should exceed 20% of the length of the edge repaired.

Requirements for treatment of such edge discontinuities more stringent than this should be specified in the contract documents, and the repair procedure should be approved by the structural engineer of record.

1.3. Ordering Steel

1.3.1. What information is required to be reported in a material test report (MTR)?

The information required to be reported in an MTR is as given in ASTM A6/A6M-Section 14 for hot-rolled shapes and plates. This includes but is not limited to the steel grade and nominal sizes supplied and tension test results. This document may be in written form or, per ASTM A6/A6M-Section 14.8, transmitted electronically.

ASTM A500/A500M Section 18 addresses this for HSS. ASTM A53/A53M Section 20 addresses this for steel pipe.

1.3.2. What are domestic purchasing requirements?

Two *Modern Steel* articles, "Made in America?" (02/09) and "The Buy American Act and the Structural Steel Industry" (10/11), discuss this issue in detail. (Both are available at (**www.modernsteel.com**)

1.3.3. When a project is subject to a metric design requirement, what shapes are available?

ASTM A6/A6M covers the metric series of hot-rolled structural shapes used in the United States. Because it is a soft metric conversion, the metric series is physically identical to the U.S. Customary-unit shape series. The dimensions are given in millimeters (mm) with mass expressed in kilograms (kg); note that the mass must be multiplied by the acceleration of gravity 9.81 m/s^2 to obtain kiloNewtons (kN). The same is true for HSS and steel pipe.

Note: A soft conversion is made by directly converting the U.S. customary unit value to a metric equivalent—e.g., 1 in. equals 25.4 mm. Conversely, a hard conversion is made by selecting new values in round metric increments, such as replacing 1 in. with 25 mm.

1.3.4. To which ASTM specifications are hollow structural sections (HSS) ordered?

ASTM A500 Grade C is most common when specifying square, rectangular and round HSS. These specifications cover cold-formed production of both welded and seamless HSS; ASTM A847 offers atmospheric corrosion resistance properties similar to that of ASTM A588 for W-shapes. Pipe-size rounds (P, PX and PXX) are also available in ASTM A53 Grade B material. See FAQs **1.4.6** through **1.4.8** for additional information on HSS and pipe section designations and material grades.

ASTM A1085 is a new specification for HSS. It offers improved material properties and design wall thickness equal to nominal wall thickness, among other desirable characteristics. For more information see **www.aisc.org/a1085**.

1.3.5. What is ASTM A992?

ASTM A992 (F_y = 50 ksi, F_u = 65 ksi) is the preferred material specification for wide-flange shapes. Material ductility is well defined for A992 since a maximum yield-to-tensile strength ratio of 0.85 is specified. Additionally, weldability is improved

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since a maximum carbon equivalent value of 0.45 (0.47 for shapes with flange thickness over 2 in.) is required. ASTM A992 is written to cover all hot-rolled shapes but it is predominantly used for W-shapes.

1.3.6. Are there any differences between steel grades ASTM A572 Grade 50 and ASTM A992?

There are differences, although the two materials are similar. ASTM A992 should be specified for all W-shapes used today. It is like ASTM A572 Grade 50, but has better controls on chemistry and mechanical properties. It includes minimum values for yield and tensile strengths, a maximum ratio for yield strength to tensile strength and a maximum carbon equivalent value (also see FAQ **1.3.5**).

1.3.7. What is a "multi-certified" material?

There is overlap in the chemical, mechanical and other requirements in many ASTM specifications. For example, there is a range of chemistry, yield strength, tensile strength and other characteristics that is entirely within the requirements of ASTM A992, A572 Grade 50 and A36. Material with characteristics within this range of overlap is sometimes "multi-certified" by the producer—labeled with all ASTM material specifications it meets. Historically, this practice was most common for wide-flange material that was specified to ASTM A572 Grade 50. While the ASTM A572 specification was met, all of the requirements of the ASTM A36 specification were also met. The producers would then sell the material as either ASTM A36 or A572 Grade 50. With the shift to ASTM A992 as the base material for design and construction with wide-flange shapes, multi-certification is perhaps more of a historical note.

1.3.8. How can shape availability be determined?

AISC has producer listings at **www.aisc.org/steelavailability** for hot-rolled shapes and HSS of various sizes and weights. Shapes producers have the ability to update these lists on a real-time basis. Contact information for many shapes producers is given on the website.

1.4 Other General Information

1.4.1. Color combinations are commonly used to indicate various steel grades. Where are these color combinations established?

Colors that identify the various grades of structural steel used to be established in ASTM A6/A6M.The requirement for color coding has been eliminated and is no longer required.

1.4.2. Where are chemistry requirements for structural steel specified?

Chemistry limitations and requirements are specified in certain ASTM specifications for structural steels, such as ASTM A36, A572, A588, A992, etc. Steel producers are required to report steel chemistry for each heat of steel produced on an MTR (see FAQ **1.3.1**).

1.4.3. Structurally, is there a difference between a ½ × 4 bar and a ½ × 4 plate?

Structurally, no. Furthermore, plate is becoming a universally applied term. However, the historical classification system for such structural material would suggest the following physical difference: All four sides of a ½ × 4 bar would be rolled edges—i.e., the mill rolled it to that thickness and width. A ½ × 4 plate will have been cut from a ½-in. plate of greater width either by shearing or flame cutting.

1.4.4. What are the common length limits on structural steel members as ordered from the mill?

Common mill lengths range from 30 ft to 65 ft in 5-ft increments. However, because individual mill practices and standards vary, it is best to consult with individual mills directly. When steel is purchased from a service center, the selection of available lengths may be further limited. Additionally, the method of shipment may also limit the available length.

1.4.5. What are the sizes of fillets for W-shapes?

Per Section 12.3.1 of ASTM A6, fillet radii are an unspecified dimension. As such, they are manufacturer-specific. Contact an individual manufacturer directly for additional information.

AISC performs a periodic survey of producers' practices to determine the minimum and maximum fillets used in shape production. The results of that survey are used to establish values in the AISC *Manual*, such as T, k_{des}, k_{det} and k_1, which are detailing values. T, k_{det} and k_1 are based upon the largest reported fillet radius, which ensures that potentially large fillet radii will not lead to fit-up problems. k_{des} is a design value based upon the smallest reported fillet, which ensures that the strength will not be overestimated in a design calculation no matter what the fillet size.

1.4.6. What is the difference between a round HSS and a pipe?

Round HSS are intended to be used as structural members. Pipe, though sometimes used as structural members, is intended to be used for mechanical and pressure applications. As used in the AISC *Steel Construction Manual*, steel pipe and round HSS are manufactured to meet different ASTM standards. Steel pipe is made to requirements in ASTM A53 Grade B (F_y = 35 ksi).

Pipes up to and including NPS 12 are designated by the term Pipe, nominal diameter (in.) and weight class (Std., x-Strong, xx-Strong). NPS stands for nominal pipe size. For example, Pipe 5 Std. denotes a pipe with a 5-in. nominal diameter and a 0.258-in. wall thickness, which corresponds to the standard weight series. Pipes with wall thicknesses that do not correspond to the foregoing weight classes are designated by the term Pipe, outside diameter (in.) and wall thickness (in.), with both expressed to three decimal places. For example, Pipe 14.000·0.375 and Pipe 5.563·0.500 are proper designations.

Round HSS are usually ASTM A500 Grade C (F_y = 46 ksi). They are available in cross sections matching each of the cross sections for ASTM A53 Grade B steel pipe. For example, an HSS 6.625×0.280 has the same dimensional properties as a Pipe 6 Std. Additionally, ASTM A500 HSS can be obtained in many more sizes with periphery not exceeding 64 in. and wall thickness not exceeding ⅝ in.

One important difference, especially from an architectural perspective, is that round HSS will have an outside diameter equal to the nominal diameter, but the outside diameter of a pipe will vary depending on its thickness. The tolerances on A500 HSS also tend to be tighter than those on A53. For example A53 requires only that the pipe be reasonably straight, where A500 places a specific tolerance on straightness. Also, A53 specifically allows dents with depths up to the lesser of 10% of the pipe diameter or ¼ in.

1.4.7. What is the difference between a tube shape (TS) and HSS?

Structurally, there is no difference. The Steel Tube Institute, an organization representing the manufacturers of hollow structural sections, initiated the change from "tube" to "HSS" in 1997 to conform to their designation practices. Thus, "TS" is simply an outdated way to specify "HSS."

1.4.8. What is the appropriate call-out for HSS?

Rectangular HSS are designated by the mark "HSS," overall outside dimensions (in.) and wall thickness (in.), with all dimensions expressed as fractional numbers. For example, a square HSS should be designated as HSS8×8×⅜ (instead of the old TS8×8×⅜). A rectangular HSS should be designated as HSS5×3×⅜ (instead of the old TS5×3×⅜). Round HSS are designated by the term "HSS," nominal outside diameter (in.) and wall thickness (in.) with both dimensions expressed to three decimal places. For example, a round HSS should be designated as HSS5.563×0.258.

Note that ASTM A53 steel pipe designations (e.g., Pipe 5 Std., Pipe 5 x-strong, etc.) are designated differently than round ASTM A500 HSS.

1.4.9. What is COR-TEN steel?

COR-TEN is a U.S. Steel trade name for ASTM A588 weathering steel. The most common weathering material is ASTM A588 Grade A. The proper specification of weathering steel is by ASTM designation, not the U.S. Steel trade name.

1.4.10. Is structural steel recycled?

The structural steel industry is the world leader in the use of recycled material and end-of-life recycling. Structural steel beams and columns produced in U.S. mills have an industry average recycled content of 93% and a recycling rate of 98%. ■