In this second of three articles, we continue the discussion of evaluating unlisted materials based on a list of factors provided in the Commentary to Section A3 of the AISC *Specification*.

steelwise

UNLISTED MATERIALS – PART 2

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STEELS APPROVED FOR use with the AISC *Specification for Structural Steel Buildings* (ANSI/AISC 360, www.aisc.org/specifications) are typically required to be "killed."

When this is not explicitly stated in a given ASTM specification, there are likely reasons that the killed steel has been used to manufacture the product. Most materials used in the U.S. are continuously cast, a process that is efficient but demanding on the producer. The requirements a producer must meet to successfully produce steel provide such benefits as better through thickness properties and soundness. Ingot cast material is still permitted and can be killed, semi-killed, rimmed or capped. (For definitions of these terms, please see the "Steel Terms" sidebar on page 18.) All material listed in Section A3 of the *Specification* meets these requirements.

Tolerances

The effect of dimensional tolerances that are different from those provided in the approved ASTM specifications must be carefully considered. Section M2.6 of the AISC *Specification* requires the dimensional tolerances to be in accordance with Chapter 6 of the AISC *Code of Standard Practice for Steel Buildings and Bridges* (ANSI/AISC 303, www.aisc.org/specifications). Section 6.4.2 of the *Code* in turn references the "applicable ASTM standards" for straightness tolerances. If there is no applicable ASTM standard (or other source of a straightness tolerance such as the dimensional tolerances of welded steel members provided in AWS D1.1) then the tolerance must be defined in the contract documents. Tolerances introduced after the contract has been awarded represent a revision to the contract as addressed in Section 9.3 of the *Code*.

Tolerances can affect many aspects of a project. The most obvious effect will be on the plumbness, elevation and alignment of the structure. Experience has shown that the erection tolerances in Section 7 of the *Code* can be met using typical fabrication and erection practices when the mill tolerances in the appropriate ASTM specification and the fabrication tolerances defined in the various documents referenced from the AISC *Specification* are satisfied. Similar experience does not exist for the full range of materials that might be available in the marketplace. The specifier is ultimately responsible for ensuring that the accumulation of the mill and fabrication tolerances do not cause the erection tolerances to be exceeded, as indicated in Section 7.12 of the *Code*. If the tolerances for the substituted material are larger than those permitted in the ASTM specifications, then the fabrication tolerances may have to be tightened, the erection tolerances relaxed or both.

In addition to the effect that material tolerances may have on other tolerances, they also may affect the methods used to design the structure. Many of the design methods used in the *Specification* are implicitly or explicitly tied to the tolerances contained in the ASTM specifications approved for use with the AISC *Specification*.

For example, Section C2.2 of the *Specification* requires consideration of initial system imperfections in the position of points of intersection of members. There is no requirement to consider the initial out-of-straightness of the member. This is because the initial out-of-straightness is already considered in the design equa-

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tions. The User Note in Section C2.2 states: "Consideration of initial out-of-straightness of individual members (member imperfections) is not required in the structural analysis when using the provisions of this section; it is accounted for in the compression member design provisions of Chapter E and need not be considered explicitly in the analysis as long as it is within the limits specified in the *Code of Standard Practice*." When the out-of-straightness is outside the limits specified in the *Code*, a more advanced analysis that includes modeling of member imperfections should be performed.

It can be assumed that any limit state related to stability will be affected by tolerances outside the limits provided in the ASTM specifications that are approved for use under the AISC *Specification*. Stability-related limit states include (but may not be limited to) lateral-torsional buckling of flexural members, the limit states addressed in Chapter E and local buckling. The width-to-thickness ratios provided in Tables B4.1a and B4.1b may not be applicable to compression elements with tolerances outside the limits provided in the ASTM specifications that are approved for use under the *Specification*. The bracing requirements in Appendix 6 also may not be applicable. The engineer of record (EOR) must evaluate the applicability of the checks provided in the *Specification* and if necessary, develop alternative checks to account for the greater tolerances.

Steel Terms

Killed steel is steel that has been completely deoxidized by the addition of an agent before casting, so that there is practically no evolution of gas during solidification. Killed steels are characterized by a high degree of chemical homogeneity and freedom from gas porosity.

Semi-killed steel refers to a type of metal alloy compound of iron and carbon that has been partially deoxidized with minimal gas release during solidification.

Rimmed steel is a low-carbon steel that contains an amount of iron oxide such that continuous generation of carbon monoxide during solidification is not inhibited. Rimmed steel is virtually free from voids and is easily bendable and cleanable. Most rimmed steels contain less than 0.1% carbon.

Capped steel starts as rimmed steel but partway through the solidification, the ingot is capped. This can be done by literally covering the ingot mold or by adding a deoxidizing agent. The top of the ingot then forms into a solid layer of steel, but the rim of the rest of the ingot is thinner than in rimmed steel.

Another option might be to impose additional project-specific tolerances. Establishing project-specific tolerances can be complex and should ideally involve all affected parties. Very tight tolerances may lead to more efficient designs relative to member sizes but may be prohibitively expensive relative to mill production, fabrication and/or election.

Testing

The ASTM specifications approved for use with the *Specification* obviously contain limits on mechanical property and chemistry. They also contain requirements related to testing. When evaluating unlisted materials it can be just as important to understand how values associated with various properties were obtained as it is to know the values themselves. For example, how fast a tensile test is run or where the sample is taken within the section can have a significant impact on the reported yield stress.

Reporting

The ASTM specifications approved for use with the AISC *Specification* also contain requirements related to reporting. For example, ASTM A6 does not place a limit on boron, and boron is generally not added to approved steels. However, if boron is intentionally added, it must be reported. There are also reporting requirements related to heat treatment. Some of the approved specifications permit material substitutions but require that such substitutions be reported. The specifier of any unlisted materials should carefully consider what is and is not required to be reported.

Alloying Elements

Steel is iron with a small percentage of carbon, and the steel we use is all alloyed to some degree. The most common and prevalent alloying elements are manganese, silicon or aluminum, copper, columbium (also known as niobium) and vanadium. Chromium and nickel are added to weathering steels, and phosphorus and sulfur are also present. Many other elements can be present as well, particularly in scrap-based steels, but they are in small proportions that should not affect steel properties or usability in a detrimental fashion.

Some in the construction industry have expressed concerns about the presence of unusual alloying elements in structural steel. These concerns may be prompted by news reports and actions taken here and abroad. U.S. producers generally have no incentive to add alloying elements that are not required by the ASTM standards to their products. However, alloy steel is often treated differently than carbon steel or high-strength, low-alloy steel relative to customs and tax laws in some countries. This may incentivize producers to add elements to their products, which may be reported to qualify for such preferential commercial treatment but may not be reported to the purchaser or end user. Legal and technical definitions of alloy steel can vary. If there is a known incentive for a producer to add alloying elements to their products, then it may make sense to require testing for such elements. Note that the mere presence of an alloying element does not necessarily indicate that any beneficial or detrimental effects on the steel have occurred. Further testing may be required to determine the effects. See the sidebar for more information.

Boron

In the last few years, other countries have reported that boron has been added to steel for commercial, not for metallurgical, reasons. Boron is added to steels by metallurgists for two reasons: making deep-drawing sheet and increasing hardenability for high strength after heat treating. Though only very small proportions of free boron are required to have the desired effect, boron reacts aggressively with oxygen and nitrogen dissolved in steel. Therefore, boron only produces the intended metallurgical effect if it is added to the molten metal in the right sequence with other elements to combine with the oxygen and nitrogen, or in large enough proportions that even after combining with the oxygen and nitrogen some free boron remains.

Since boron is not required in the steels we use and it is difficult to measure in the precision of interest, it is not measured or reported on material test reports of steel plates or shapes. ASTM A514 is an exception where many grades do require boron. ASTM A6 requires boron to be measured and reported only if it is intentionally added and states: "For steels that do not have intentional boron additions for hardenability, the boron content will not normally exceed 0.0008%."

The intended meaning can be difficult for steel users to determine. Steel with high hardenability is susceptible to weld cracking, but at the right level boron will help achieve the required strength. Boron is also present in some SAW and FCAW filler metals. (An independent testing lab that has tested multiple samples of steel plate in Canada reports boron composition as being between 0.01% and 0.02%.) An informal survey of major filler metal producers indicates that they have not become aware of weld cracking attributed to boron. If weld cracking that is not a result of other causes occurring, testing for boron would be a reasonable response. ■

The discussion on evaluating unlisted materials will conclude in Part 3 of this three-part series, which will appear in next month's issue. For Part 1, see the October 2018 issue at www.modernsteel.com.

Unfamiliar Producers or Suppliers

Though not directly related to the use of unlisted materials, engineers and fabricators may also have concerns about the use of material from producers that are not familiar to us. The AISC *Specification* does not treat steel any differently based on where it is produced or who produces it. Users of structural steel products (owners, general contractors, engineers, fabricators and authorities having jurisdiction) are free to introduce reasonable measures to protect the interest of designers/builders and their clients. Restrictions and additional requirements must be imposed contractually. If such measures are introduced after the contract has been agreed to, such measures would likely be considered a change to the contract.