In this third and final article in our series, we continue the discussion about unlisted materials, this time focusing in on considerations beyond those listed in the Commentary to the AISC *Specification*.

steelwise

UNLISTED MATERIALS – PART 3

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IN ADDITION TO the considerations listed in the Commentary to the *Specification for Structural Steel Buildings* (ANSI/AISC 360, available as a free download at **www.aisc.org/specifications**) there are other factors that might also be considered when contemplating the use of unlisted materials. We'll discuss them here.

Equivalency

Engineers and contractors often use the term *equivalent* when discussing unlisted materials. The party proposing the substitution will often claim that the proposed material is equivalent to a listed material, or the engineer will ask about the equivalency of two different materials. This sort of thinking misses at least half the issue.

In some instances, it may be possible to specify a more general material in such a way that it becomes equivalent to some other more specific material. In such cases, the material could likely be dual- (or multi-) certified rather than being treated as a substitution. Setting aside this possibility, it is unlikely that two specifications will be wholly equivalent. There will be differences. This means that equivalency must be judged not just considering the material side but also the application side. The two materials are not identical, but can they function in an effectively identical manner in a given application? Both the proposed material and the proposed application must be considered together.

In other instances, a single material can satisfy multiple ASTM specifications. Such materials are sometimes supplied as dual- or multi-certified materials, and multiple ASTM specifications will be listed. The most common condition seen in building construction is some combination of A36 with ASTM specifications for approved steels with a yield strength of 50 ksi. This is possible because ASTM A36 does not provide a limit on the maximum yield strength. For most building applications, the greater strength is not a concern. In some cases, such as in the AISC *Seismic Provisions for Structural Steel Buildings* (ANSI/AISC 341, **www.aisc.org/specifications**), the material over-strength is explicitly accounted for (i.e., in the values for R_y and R_t).

There are, however, applications for which greater yield strength could be detrimental to the design intent. These applications generally fall outside the scope of the *Specification*. In such cases, the specifier must either specify a limit on maximum yield strength or adjust the design to accommodate readily available materials. It should be noted that obtaining ASTM A36 material with a yield strength near 36 ksi can be exceedingly difficult.

Seismic Considerations

The *Seismic Provisions* treats material selection differently than the *Specification*. Section A3.1 states: "The structural steel used in the SFRS described in Chapters E, F, G and H shall meet one of the following ASTM Specifications…" and provides a list of permitted materials. The permitted materials have been selected to be consistent with tested seismic systems and to reflect desirable seismic performance characteristics (e.g., ductility or limited maximum yield strength) consistent with the requirements of the *Seismic Provisions*.

Even if other materials were not explicitly prohibited, their use in the seismic force-resisting system (SFRS) could be difficult due to lack of expected material strengths

established to be consistent with the *Seismic Provisions*. The lack of values for R_y and R_t effectively excludes the use of unlisted materials for yielding elements and makes correct implementation of some provisions virtually impossible.

Steel Castings and Forgings

Section A3.2 addresses requirements for castings and forgings and states: "Steel castings and forgings shall conform to an ASTM standard intended for structural applications and shall provide strength, ductility, weldability and toughness adequate for the purpose." The use of standards not produced by ASTM or not intended for structural applications is prohibited under the *Specification*.

Consumables for Welding

Section A3.5 addresses requirements related to welding consumables and states: "Filler metals and fluxes shall conform to one of the following specifications of the American Welding Society…" A list of permitted filler metals is provided. The use of other filler metals is prohibited. Note that other codes may permit the use of other filler metals.

Headed Stud Anchors

Section A3.2 addresses requirements for headed stud anchors and states: "Steel headed stud anchors shall conform to the requirements of the *Structural Welding Code—Steel* (AWS D1.1/D1.1M)." The design of composite beams using steel headed stud anchors is semi-empirical. Therefore, the configuration and installation of the anchors must conform to the testing that has been performed.

Alternative-Design Fasteners

The *RCSC Specification for Structural Joints Using High-Strength Bolts* provides requirements for the use of alternative-design fasteners. The requirements provided in the *RCSC Specification* should be viewed as minimum requirements. The use, installation and inspection of alternative-design fasteners are subject to evaluation by the engineer of record (EOR).

Substitution Materials

The reason for the proposed substitution of material should be considered when evaluating an unlisted material. Sometimes, substitutions are proposed because the specified material is not available or will not be available in time to meet the project schedule. In such cases, the goal should be to find a product that is as similar as possible to the preferred material. Evaluating the material could be a simple as comparing the two specifications, identifying differences and then taking steps to either bring the substituted product into better alignment with the original product or ensure that the difference will not be detrimental to the design. This latter option may involve design changes. Of course, the best way to avoid these situations is to specify the preferred materials listed in Part 2 of the AISC *Steel Construction Manual* (**www.aisc.org/manual**) and to discuss availability with fabricators likely to bid the project.

One reason material substitutions are requested is that the approved materials may not be made where the material is needed. The substitution effectively increases the number of producers and potentially the quality of their practices and equipment. Where producers are well known and their products are in frequent use in similar structures, routine quality assurance practices are sufficient. However, where producers are not well known, extra precautions such as tensile tests and chemical composition tests by independent laboratories of a sample of the product may be justified. It is the engineer who must both specify the tests to be conducted and evaluate the results.

There are, of course, other reasons an engineer may want to consider a material substitution. It may be that some material is especially well suited to the design of the project. For example, ASTM A992 and ASTM A1085 both existed as ASTM specifications prior to being approved under the *Specification*, and some engineers may have wanted to take advantage of some of the improvements inherent in these specifications. There are also specialty fasteners that permit bolting from one side only that, while not approved for use under the *Specification*, are relatively common in hollow structural section (HSS) connections.

However, the motivation for a proposed substitution can sometimes be more controversial and the evaluation more complex. The AISC Steel Solutions Center has received a number of inquiries involving conditions where either EORs or contractors have proposed to substitute ASTM A354 Grade BD bolts for ASTM F3125 Grade A490 bolts. ASTM A354 is a listed product in both Sections A3.3.(a) and A3.3.(b). ASTM A354 Grade BD is also included in Group B in Section J3.1. The *Specification* states: "When bolt requirements cannot be provided within the *RCSC Specification* limitations because of requirements for lengths exceeding 12 diameters or diameters exceeding 1½ in. (38 mm), bolts or threaded rods conforming to Group A or Group B materials are permitted to be used in accordance with the provisions for threaded parts in Table J3.2." This is the typical reason that A354 bolts are specified—because F3125 bolts of the required diameter or length are simply not manufactured.

That said, there have been instances of A354 Grade BD being substituted for F3125 Grade A490 bolts to get around the explicit prohibition against galvanizing A490 bolts. What is missed in this process is the fact that A354 Grade BD could be viewed as a more general version of F3125 Grade A490. By properly addressing all of the relevant parameters, it would be possible to specify a bolt that satisfies both A354 Grade BD and F3125 Grade A490. If this is done and nothing more, then it would seem that the prohibition against galvanizing should apply regardless of whether

one chooses to label the bolt A354 Grade BD or F3125 Grade A490. There are additional steps that can be taken that might lessen concerns about hydrogen embrittlement. If an engineer chooses to substitute A354 Grade BD for F3125 Grade A490 to provide a bolt that is galvanized, the engineer is responsible for evaluating the potential impact of the decision and deciding what additional steps should be taken when specifying the bolt.

When cost is the primary driver for a substitution, additional caution may be warranted on the part of the engineer. Safety and the performance of the structure should be the primary consideration during the evaluation of the proposed substitution. Even when all parties share the goal of having a successful project, it should also be kept in mind that the various parties involved may have different perspectives, spheres of knowledge and motivations.

Intended Use

When evaluating proposed substitutions, it can often be useful to look into the common or intended uses for the proposed materials. Engineers may be more comfortable and the evaluation simpler when the proposed material is commonly used for structural applications. The deliberation may be considerably more complicated and time-consuming when steel commonly used to manufacture automobile crankshafts is proposed to be used to fabricate anchor rods, or steel commonly used in refrigerator bodies is proposed to be used in the fabrication of single-plate shear connections. These substitutions may or may not be suitable, but they certainly seem less intuitive.

All the Stuff You Usually Get for Free

The materials approved for use with the *Specification* are approved because they are commonly used in the construction of structural steel buildings, and in many cases have been developed and manufactured with structural steel buildings in mind. It is important to understand that the specification associated with the proposed material may be more general than the originally specified material or the approved materials. When you specify an approved material, parameters are likely specified that make the material especially useful as structural components in a building.

When a substitution is made, it may be necessary to impose additional project-specific requirements beyond what is included in the standard specification. For example, ASTM A500 includes tolerances on outside dimensions, wall thickness, straightness, squareness, twist and other parameters. When a similar HSS is specified to be fabricated from plate, the specifier should carefully consider which of these parameters, if any, need to be controlled, and take measures to do so. In some instances, tolerances from other standards like AWS D1.1 may be applicable, but it should be kept in mind that these tolerances are often tied to the intended use—i.e., whether it is a column or a beam, which may not always be obvious in the contract documents.

Though not necessarily involving a substitution, specifying bolts and threaded parts provides a good example of an issue that can arise. If a bolt or anchor rod is specified as F3125 or F1554, most of the required parameters are already included in the specification and need not be deliberated and provided by the specifier. However, as the specifications become more general, more of these parameters must be defined by the specifier. One of the advantages A354 has over F3125 is that A354 permits a wider range of fasteners to be produced. However, this flexibility means that the specifier has to consider and provide more information. Going a step further, anchor rods are sometimes specified using even more general specifications like A36. This can be done, but it must be recognized that A36 contains no provisions that directly address fasteners, so all of the fastener-related parameters theoretically must be defined by the specifier. In practice, the contrac-

tors or suppliers often decide what will be provided when the contract documents are not clear, and use of the products is confirmed through the approval process. This process, though not ideal, often proved sufficient.

When considering the use of unlisted material, the specification should be carefully examined to ensure that all pertinent properties are addressed. Very general specifications should be avoided or supplemented with project-specific requirements.

A Team Effort

The use of unlisted materials can impact multiple members of the project team, sometimes in unexpected ways. These effects must be considered.

As described above, evaluating unlisted materials is not always simple. Significant engineering time and effort may need to be dedicated to evaluating the proposed material. In some instances, experts may have to be brought in, as structural engineers often do not possess specialized knowledge of metallurgy or welding that may be required in the evaluation. The project budget and schedule must accommodate these factors. If it is decided that additional requirements must be enforced, then the affected parties must work together to determine what is necessary, what is possible and what is practical.

If toughness is a design consideration but the toughness of the proposed material is uncertain, the engineer may want to impose minimum toughness requirements and impose toughness testing—but this will be to no avail if the material specified simply cannot meet the specified requirements.

If a large quantity of bent plate is required but the material specified proves to be susceptible to cracking when formed using typical shop practices, who is responsible for the costs associated with retooling, retraining and re-fabrication?

If the proposed material has a straightness tolerance significantly larger than that of the approved materials but the project specification requires a tighter straightness tolerance, how is this to be achieved? Will the mill supply straighter members than is typical? If so, how will this be done and will there be any detrimental effects to other material properties? Will the members be straightened by the fabricator and if so how—via heat straightening or cold straightening? If the material is damaged using typical shop straightening processes, who is responsible for the repair or replacement of the material?

These are the sorts of issues that may have to be addressed by the project team. The team should be prepared to address them, preferably in a proactive manner. It is often much more difficult and expensive to fix a problem than to prevent the problem from occurring in the first place.

Comparisons to Other Codes

As stated near the beginning of this article, the *Specification* is commonly referenced by other codes and used at the discretion of engineers for applications outside its stated scope. It is important to understand, however, that there are limitations to its applicability. Comparing the AISC provisions to those of other codes and information provided in guides and texts can sometimes provide the engineer with additional insight.

For example, some engineers simply apply provisions of the *Specification* to the design of stainless steel. In some instance, this may produce acceptable results, but stainless steel and structural steel as addressed in the *Specification* are different materials that sometimes require different considerations to be made. AISC Design Guide 27: *Structural Stainless Steel* (**www.aisc.org/dg**), though not a formal specification, provides design guidance that is more appropriate for stainless steel. Since the guide includes nearly provision-by-provision comparisons, modifications and discussions related to the design of stainless and structural steel, it provides useful and unique insight into the process of evaluating the different materials that might at first glance appear to be pretty similar or even equivalent.

One interesting recommendation involves making net section checks using the yield strength, F_y, rather than the tensile strength, F_u, used in the *Specification*. This is done, as explained in the guide, because stainless steel is twice as ductile as carbon steel and the *Specification* procedures could lead to larger-than-expected (and possibly unacceptable) deformations if applied to stainless steel. This is a case where a generally desirable property, increased ductility, could produce deleterious effects when combined with design provisions intended for use with a limited range of materials. An alternative to basing the net section strength on the yield strength might be to explicitly account for the increased deformation. Relative to stability, Section C1 of the *Specification* already requires consideration of "flexural, shear and axial member deformations, and all other component and connection deformations that contribute to the displacements of the structure." In practice, there are many sources that are considered, but their effects are neglected based on engineering judgment. When unlisted materials are specified, common design (and construction) practices may have to be reevaluated.

Comparing the *Specification* and the *North American Specification for the Design of Cold-Formed Steel Structural Members* is another exercise that can provide insight to engineers relative to design considerations that may have to be made when evaluating or designing unlisted materials. Both documents address members made from steel. However, there are many differences between the provisions due to the different materials and applications addressed.

Specifications also vary based on the application. Though the same materials are commonly used to construct both buildings and bridges, there are different specifications used for the two applications.

The possibility that a code exists that better addresses the design of the unlisted material should also be considered.

Approved by Others

There are other organizations that approve the use of steel materials and products. Though such approval may or may not indicate that the approving organization feels that the material can be implemented using the *Specification*, the approval cannot be taken to indicate that the material is approved by the *Specification*. Only the listed materials have been approved by the AISC Committee on Specifications.

Final Thoughts

Unlisted materials have been successfully used in structural steel buildings to provide safe and economical solutions to conditions that are outside the scope of the *Specification*. However, the use of unlisted materials should not be taken lightly by either the EOR or the contractor. In some instances, it might be possible to apply provisions of the *Specification* and/or the *Code* to the unlisted material, though some modification of either the provision itself or its implementation may be necessary. If this path is taken, it is done at the discretion of the specifier. ■

*Parts 1 and 2 of this series appeared as SteelWise articles in the October and November 2018 issues, which you can view at **www.modernsteel.com**. And to contact the AISC Steel Solutions center, visit **www.aisc.org/solutions**.*