Material Substitutions

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Just because something is not on the list of approved materials does not mean it is prohibited, which is where the engineer's evaluation and judgment come into play.

SECTION A3 OF THE AISC *SPECIFICATION* lists a number of material standards as being "approved" for use with the AISC *Specification*. These materials are the mainstay of steel building construction, with the usual materials used in routine applications and listed alternatives selected in special cases.

Occasionally, a special need or interest creates the question about one of the many other steel material standards that do not appear in Section A3. These materials lack the pedigree of being "approved" in Section A3 for use with the AISC *Specification*. Does this mean that they cannot be used?

The short answer is no. The engineer of record always has the prerogative to decide that another suitable material is acceptable.

It is a practical matter that only the usual materials and common alternatives are listed in the AISC *Specification*. With well over 6,000 enumerated steel material standards alone, it is effectively impossible to consider fully every possible steel material. There simply aren't enough committees, or enough time in a code cycle, to develop official recommendations (to say nothing of the difficulty in keeping track of the individual development paths for each of those 6,000-plus standards). By the time anything got decided, the decision would likely be obsolete. Because the relevant committees have not considered other materials, their evaluation and acceptability is a matter for the engineer who specifies them (see the Commentary to the AISC *Specification*, Section A3.1a).

Making an Evaluation

There are no simple tables of equivalence that will indicate if one material is "equal" to another because there is no single optimal way to evaluate the use of a new/different material. The exact method of evaluation inevitably depends upon the individual project requirements: what is appropriate for a particular purpose in one project may be less so or wholly inappropriate for another project.

To take an extreme example, consider a 5-lb wedge of A992 steel and a 5-lb wedge of tungsten. Both could be used to make doorstops, but the tungsten wedge will cost about 10 times as much as the steel wedge. Conversely, when designing an antitank missile penetrator tungsten is likely to be far more appropriate when used against armored targets. Tungsten and carbon steels are rarely considered to be "equivalent" materials, but for the purposes of being a doorstop they might be close enough to be considered comparable.

Of course, a wedge of rubber might be a wiser choice, as rubber has certain characteristics that are desirable in doorstops (e.g., ability to deform without damage to itself or nearby surfaces) and would be both lighter and cheaper.

The point of all this is that one cannot make a determination that two materials are equivalent without knowing for what they're going to be used and what qualities are most important to that function. This is a project-specific determination that must be made by the engineer of record.

Following is a list of considerations that may be relevant when considering the use of a material other than those referenced in the AISC *Specification*. It is not necessarily an exhaustive list, should not be treated as a "checklist," and cannot replace the professional judgment of the engineer of record.

F_y and F_u

When considering a proposed material substitution, perhaps the two most requested properties of the substituting material are the yield strength and the tensile strength. The reasons for this are obvious enough, but one should remember that outwardly-similar materials can behave very differently in ways that are not always apparent from the numerical values of F_y and F_u at first glance.

There are, of course, ways to adjust for this behavior (such as the "0.2% offset rule"), but one cannot make those adjustments sensibly unless one is aware of the behavior in the first place.

Other Mechanical Properties

Elongation is also significant. All designs assume a basic capability to provide local ductility and a higher level often

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is demanded in high-seismic applications. Strain hardening characteristics also reside in the background, and have become somewhat explicit in high-seismic design provisions.

While it is nominally similar for grades of carbon steel, the coefficient of thermal expansion can be markedly different for other types of steel materials considered for structural use.

Another consideration: is the material such that fabrication is different? Drills might require special bits or different speed/feed parameters, shears may have to be down-rated, blade clearances may have to be tweaked, hold-downs reinforced, and so on. These concerns are generally the responsibility of the fabricator, but it will be wise in the selection of alternative materials to discuss them with the fabricator to know what, if anything, might be different.

Chemical Properties

Corrosion. When corrosion effects are a consideration, it is important to know if the usual solutions will work for the material being considered as a substitute. This usually is straightforward, but if the substitution involves a dissimilar material this may not be the case.

Even materials that are generally very resistant to corrosion may corrode as a consequence of improper use. As two examples: stainless steel must be fabricated with separate equipment from that used for carbon steel to avoid introducing trace elements from the carbon steel (and corrosion) into the stainless steel; also, grit-blasting of stainless steels can create a surface profile that is susceptible to crevice corrosion even if the parent material would not otherwise corrode under the same conditions.

Welding. AWS D1.1 Table 3.1 lists prequalified base materials for structural steel welds. If a proposed substitution does not appear in that table it will be necessary to develop a WPS through testing and there will be an associated cost.

Different materials also may behave differently with respect to their heat-affected zone. Perhaps the most famous example of this is found with aluminum, but it may need to be considered for other materials. Do not assume that "everyone" will be aware of any differences.

Quite apart from structural concerns, welding can produce different visual results, which may or may not be acceptable for the project. If materials are substituted in a project with AESS requirements, this may be a consideration if the material is to be clear coated.

Analysis and Quality Requirements

Some standards may appear to be superficially identical, but then turn out to have subtle differences in the analysis/quality sections. For example, what variations are permitted? Steel Standard X may require that the sum of columbium + vanadium not exceed 0.15%, while an otherwise-identical Steel Standard Y may simply have a maximum columbium of 0.05% and maximum vanadium of 0.15%. Given this small difference, it would be possible for Steel Y to be effectively identical to Steel X on some occasions, and to violate the requirements of Steel X on others.

Another possibility exists: let us assume that a project has specified Steel Standard X, and the design has been based upon that standard. A prospective supplier proposes a substitution, providing certified Mill Test Report listing vanadium of 0.12%, niobium of 0.04% and no columbium. On the surface it appears that this is effectively the same as Steel Standard X because the total of columbium plus vanadium does not exceed 0.15%, and niobium is not mentioned in Steel Standard X at all, so it must not matter.

As it happens, niobium and columbium are two names for the same element and the proposed substitute violates the requirements of Steel Standard X. Whether that is meaningful for the project or not is another question but absent a close reading of the relevant standards it may have escaped notice.

A related problem can be found when different standards refer to different test methods to establish adherence; a nominal value that is tested by one method can be notably different from a nominal value tested by a different method.

For example, consider again Steels X and Y. Standard X requires Test Method 1 to determine notch-toughness, while Standard Y requires Test Method 2. If Test Method 1 has a +/- 5% error and Test Method 2 has an unknown error, will Steel Y perform as expected? Absent a reliable method to correlate the results from Test Method 1 and Test Method 2 it may be necessary to perform additional testing.

Mandatory, Optional, Supplemental

Many standards incorporate optional or supplemental sections in order to cover a wider range of industry needs. In some cases, these optional/supplemental sections are almost universally used, while in others they are almost entirely ignored. When considering a substitute material with the assumption that a particular supplemental requirement be met, one should make sure that the assumption is warranted.

The mere fact that an optional requirement seems obviously useful does not mean it is obviously useful to the industry that uses the standard. One area of particular note here is weldability and carbon-equivalence; the fact that a proposed substitute standard has supplemental weldability requirements does not mean most, or even any, of the commonly-available products meeting that standard are, in fact, weldable by the processes that are common in steel fabrication.

Shapes and Surfaces

Although the majority of this article has focused on material substitutions, a few words are in order regarding shapes, surfaces, and the like. One cannot assume that two products are interchangeable simply because their material standards are acceptable; the forms that those two products take may be different in ways that affect their intended use.

Consider how product form may affect availability, tolerances, testing requirements, reporting, surface profile and characteristics, and so on. These consequences may not always be apparent at first glance.

In Summary

The mere fact that a material has not been approved for use with the AISC *Specification* does not mean that it has been explicitly rejected; it simply means that it has not been con-

sidered. The common materials used are covered and their use on a project is fairly routine. The use of other materials, however, departs from that routine and the Engineer of Record must address the acceptability of the substitute and what requirements apply if it is acceptable.

To properly use an unlisted material, one must evaluate its various characteristics in relation to the contemplated uses for it—but remember that subtle differences can be important depending upon the application. There are perhaps as many reasons for substitutions as there are materials, but even so one may also wish to consider why a substitution is being suggested. A grade of material that is initially cheaper may not turn out to be less expensive in the end, once all of the ramifications are taken into account.

Ultimately, a material must be acceptable for the particular application if it is to be acceptable as a substitution. MSC

Commentary from the 2010 *Specification*

Section A3 of the Commentary to the 2010 *Specification for Structural Steel Buildings* opens with this expanded statement concerning material properties covered by ASTM designations.

"There are hundreds of steel materials and products. This *Specification* lists those products/materials that are commonly useful to structural engineers and those that have a history of satisfactory performance. Other materials may be suitable for specific applications, but the evaluation of those materials is the responsibility of the engineer specifying them. In addition to typical strength properties, considerations for materials may include but are not limited to strength properties in transverse directions, ductility, formability, soundness, weldability including sensitivity to thermal cycles, notch toughness, and other forms of crack sensitivity, coatings, and corrosivity. Consideration for product form may include material considerations in addition to effects of production, tolerances, testing, reporting and surface profiles."

The *Specification* is available as a free download at **www.aisc.org/2010 spec**.