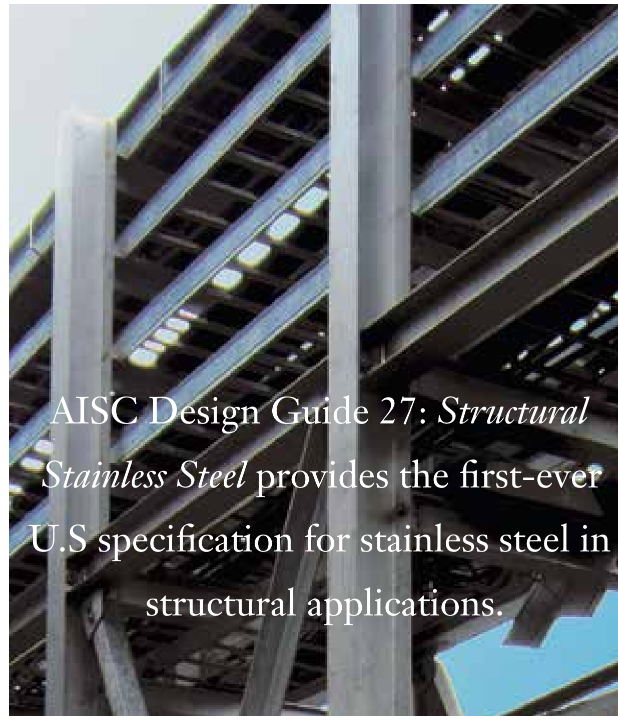
Skidmore, Owings & Merrill LLP

◄ Schubert Club Band Shell, St. Paul, Minnesota.

▼ Stainless steel framing in a nuclear power plant.



Stainless Structurals LLC

AISC Design Guide 27: *Structural Stainless Steel* provides the first-ever U.S specification for stainless steel in structural applications.

A New Guide for Stainless

BY NANCY BADDOO

SINCE ITS DISCOVERY 100 years ago, stainless steel is being used increasingly in construction for applications that can benefit from intrinsic durability, attractive appearance, strength, ductility, low maintenance requirements and formability.

It is typically used in aggressive environments such as those exposed to salt water, de-icing salts or heavy pollution. Applications run the gamut from industrial structures like platforms, barriers and gates to equipment supports for the food and beverage, water treatment, pulp and paper, nuclear, biomass, chemical and pharmaceutical industries to building and infrastructure applications like glass curtain wall supports, roofs, canopies, seismic components, security barriers, bridge elements and components in difficult-to-access areas.

While structural stainless steel is considerably more expensive than equivalent carbon steel products, the additional cost is partially offset by savings associated with eliminating corrosion-resistant coatings and reducing section size by taking advantage of the relatively high strength of duplex stainless structural steel (yield stress is 65 ksi or 450 MPa). In addition, removing the need for coating maintenance or component replacement due to corrosion can lead to significant maintenance cost savings over the lifetime of the structure—not to mention savings in the indirect costs of maintenance, such as loss of production due to facility shutdown, environmental impacts and transportation disruption.

And, the nonlinear yielding and strain-hardening characteristics of stainless steels mean that conventional carbon steel design rules, based on observing the limit of elastic deformation, do not apply; the elastic "limit" of stainless steel is not sharply defined as it strain-hardens rather than yields with the onset of plastic deformation. Therefore, when using stainless steel in structural applications, lower local buckling limits and member buckling curves apply, and slightly greater deflections are expected for beams.

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Stainless steel columns at Cornell University's College of Agriculture and Life Sciences.

A stainless steel sign support in Tampa, Fla.

Stateside Stainless

Although SEI/ASCE 8 *Specification for the Design of Stainless Steel Cold-Formed Structural Members* has been available for many years, until recently there was no U.S. design specification covering hot-rolled and welded stainless steel. This has been a major obstacle to the wider use of stainless steel structures, since designers have either needed to work from first principles or use carbon steel rules, sometimes applying an arbitrary additional safety factor.

But in 2009, work started on the development of an AISC design guide for structural stainless steel, supported by the U.S. stainless steel industry and associated market development associations: Design Guide 27: *Structural Stainless Steel*. Now available, the guide was written so that designers who are familiar with ANSI/AISC 360-10 *Specification for Structural Steel Buildings* would be able to use it without difficulty. Where stainless steel behaves in a similar way to carbon steel, Design Guide 27 simply refers to the relevant section in AISC 360. Where the guidance in the AISC *Specification* would be unconservative or unduly conservative when applied to stainless steel, specific rules for stainless steel have been presented in a format as close as possible to the equivalent expressions in AISC 360 for carbon steel.

Design Guide 27 gives detailed guidance on material properties, grade selection, specification, durability, fatigue, fabrication and erection. Design rules for members and connections (bolted and welded) are given at ambient temperatures and in fire, and six design examples illustrate the application of the design rules. These rules are intended for primary and secondary structural components made from hot-rolled and welded sections (I-sections, channels, T-sections, angles and round, square and rectangular hollow structural sections) with thickness 0.125 in. (3 mm) and greater. The guide specifically covers the popular austenitic grades 304/304L and 316/316L and the standard and lean duplex grades. Guidance is also included on the use of certain precipitation hardening grades for tension members, fixings and fasteners (these stainless steels are useful when very high strengths are needed). Not surprisingly, the scope of the design rules is more limited than the scope of AISC 360; they cover commonly encountered structural shapes and load scenarios, but not every scenario in AISC 360.

As well as nonlinearity, the stress-strain characteristics of stainless steels also display non-symmetry of tensile and compressive behaviour and anisotropy (differences in behaviour of coupons aligned parallel and transverse to the rolling direction). In general, anisotropy and non-symmetry increase with cold work and so are more significant in the design of lighter gauge heavily worked sections, which are covered by SEI/ASCE 8. The structural sections covered by Design Guide 27 are not made from heavily cold worked material, so the differences in the stress-strain behaviour due to non-symmetry and anisotropy are not large; the nonlinearity has a more significant effect.

The following procedure was followed for deriving the design rules for stainless steel in Design Guide 27:

1. Compare the rules for carbon steel in AISC 360 against all available stainless steel test data on members and connections.
2. Modify the AISC 360 carbon steel rules to suit the stainless steel data, where necessary.
3. Calculate the stainless steel resistance factors to use with the recommended stainless steel design rules.

Eurocode 3: Part 1.4 (Design of Steel Structures, Supplementary Rules for Stainless Steels) is the only other design standard available in the English language covering hot-rolled and welded structural stainless steels, and its design rules were taken into account throughout the process of deriving the rules for the new guide.

Below are a few examples of how the new guide differentiates between carbon and stainless steel:

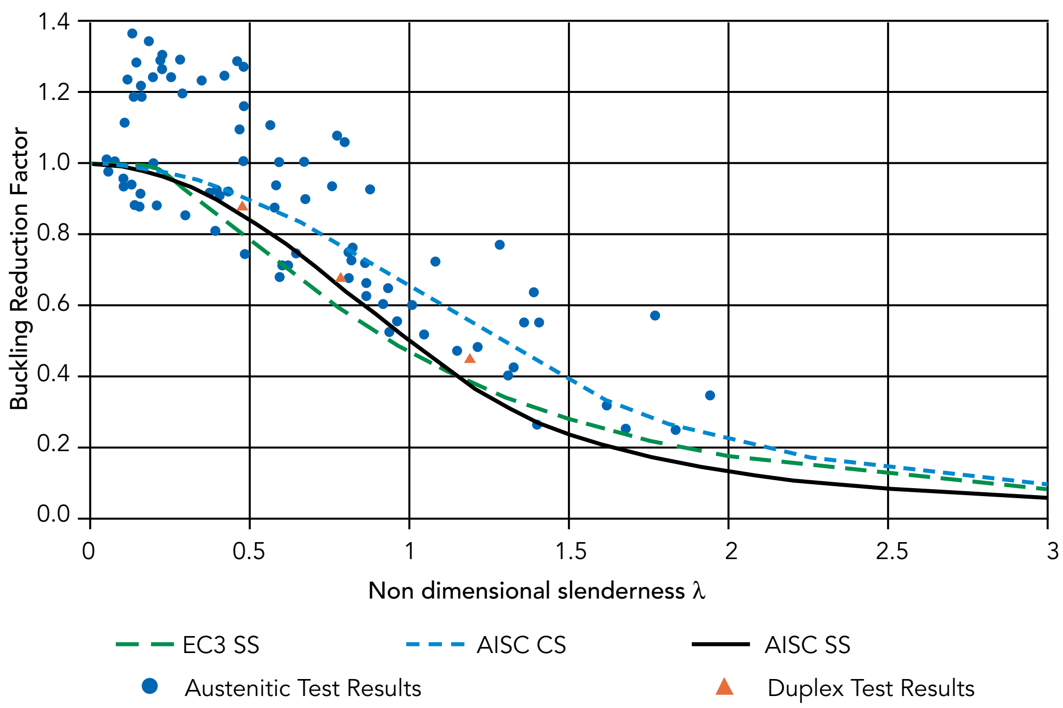
Resistance/safety factors. The resistance and safety factors were calculated in accordance with the AISC protocol for assessing the reliability of a structure, with a target reliability index for members of $\beta = 2.6$ and for connections $\beta = 4.0$. Values for the factors were derived for each expression in Design Guide 27, using an extensive database of test results. In general, the reliability analysis showed that the AISC carbon steel resistance/safety factors could be safely used with the AISC stainless steel design curves, except for round HSS in compression and fillet welds, where lower factors are given for stainless steel. Full details of the reliability analysis are given in Appendix B to the guide.

Classification of sections for local buckling. The limiting width-to-thickness ratios for stainless steel given in Design Guide 27 were derived by calibration against experimental data. They are either the same or more conservative than those for carbon steel, primarily due to the nonlinear stress-strain characteristics of stainless steel.

Members in compression. Using test data for calibration, an AISC stainless steel buckling curve was derived that retained the format of the AISC carbon steel buckling expression but contained modified coefficients. This is a different approach to that taken in SEI/ASCE 8, which takes the nonlinear stress-strain curve of stainless steel into account by replacing the initial elastic modulus with the tangent modulus corresponding to the buckling stress; this involves an iterative design procedure. For Design Guide 27, as with the Eurocode, it was considered preferable to have an explicit design solution as opposed to one requiring an iterative solution.

The AISC stainless steel buckling curve is shown in Figure 1, with the experimental data used in the calibration. The figure also shows the equivalent expression for carbon steel, as given in AISC 360 Eq. E3-1 to E3-4 and the Eurocode stainless steel buckling curve for welded open sections, buckling about the minor axis.

Figure 1. Flexural buckling curves, plotted with stainless steel experimental results.



Members in bending. The strength expressions for carbon steel in AISC 360 for yielding and flange local buckling were shown to apply to stainless steel providing the stainless steel values of λ_p and λ_r are used (as given in Table 3-1 and 3-2 of the guide). For rectangular HSS, the AISC 360 expressions for flange and web local buckling were not given in terms of λ_p and λ_r, and therefore some coefficients required modification to suit the slightly different behaviour of stainless steel. It was also necessary to modify the AISC expressions for lateral torsional buckling in order to generate a lower design curve, closer to the stainless steel test data.

Shifting toward Sustainability

Although stainless steel is considerably more expensive than carbon steel, savings in maintenance, downtime and replacement costs over the lifetime of the structure can outweigh these higher initial material costs and offer an economic alternative in certain structural applications. In addition, the shift toward more sustainable development is also opening up new opportunities for stainless steel, demonstrating that it has a unique and long-term contribution to make in fulfilling human needs while maintaining the quality of the natural environment. **MSC**

AISC Design Guide 27: Structural Stainless Steel *is available at www.aisc.org/designguides.*

Interserve

▲ Stainless steel beams at Thames Gateway Water Treatment Works.

Catherine Houska

➤ Stainless steel HSS used for the entrance canopy in Seven World Trade Center. The cable net wall incorporates tensioned high-strength stainless steel cables to support the façade.

Sponsoring Stainless

The preparation of AISC Design Guide 27 was sponsored by the following entities:

- Specialty Steel Industry of North America (SSINA)
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