Volume 56, First Quarter, 2011

australasian welding JOURNAL

PUBLISHED BY THE WELDING TECHNOLOGY INSTITUTE OF AUSTRALIA

This issue: ***Fabrication of High Strength Steels*** ***and Welding Research Supplement***

PRINT POST APPROVED PP 255003/01892

High(er) strength steels in structures – Engineering and welding considerations

Doug Hawkes – Principal Structural Engineer, Structural Integrity Engineering Pty Ltd

'Higher' strength structural steels are becoming more highly utilised in structural steel construction, where 'Grade 350' type steels are often used due to the advantages of:

(a) additional strength for the same steel weight;

(b) less weight for a reduced transport cost, which is important for overseas fabrication.

(c) the ever-increasing availability (in various standard designations).

The days of 'Grade 250 mild steel' are most likely numbered. Of course there are many high strength steel options for both structural and other applications.

This article is generally reviewing the relatively common 'higher' strength structural steel around the yield strength of 350 MPa, and addresses a number of issues surrounding the use of these steels, particularly when being sourced from overseas steel mills.

In combination with these gains in material strength, additional consideration must be given to issues such as material substitution, weldability and long term structural maintenance issues.

Material used for design versus the procured fabrication material

The consideration of the likely materials of construction is required as early as possible in a project.

Alignment of the original design requirements and design intentions with the fabrication practices, including the materials of construction, is of vital importance both technically and economically.

This is most aptly described in the following phrase from the foreword of ISO 2394 *General principles on reliability for structures*:

"It is important to recognize that structural reliability is an overall concept comprising models for describing actions, design rules, reliability elements, structural response and resistance, workmanship, quality control procedures and national requirements, all of which are mutually dependent.

The modification of one factor in isolation could therefore disturb the balance of reliability inherent in the overall concept".

Many Design Engineers are not aware of the 'common' worldwide steel standards. Australian standard materials may not be used for a particular design, even if it is being fabricated in Australia! These could include Euronorm Standards such as EN 10025 and EN 10210, or Chinese Standards such as GB/T 1591, GB 700 and GB/T 8162, or American Standards ASTM A 36 or A 572, not to mention BS, JIS or DIN standards as well.

A key difference between most other international standards and the structural steel Australian/New Zealand Standards AS/NZS 3678[1], AS/NZS 3679[2] and AS/NZS 1163[3] is that the international standards yield strengths are generally lower for the nominal and industry common, but poorly termed, 'Grade 350' type steel. The grade designation of steels (i.e. Grade 350, S355, Q345 etc) is *generally* defined as the yield strength for up to 16 mm thick-

(Continued on page 18)

High(er) Strength Steels

(Continued from page 18)

ness. As thickness increases, yield strength generally decreases *for the same grade.*

Take the following examples of 20 mm and 50 mm plate for the relevant AS/NZS Standards and for two overseas standards.

Standard and Grade	Yield strength (MPa)	
	20 mm	50 mm
AS/NZS 3678 Grade 350	350	340
EN 10025 Grade S355	345	335
GB/T 1591 Grade Q345	325	295

The above table shows up to 45 MPa, or 13% difference between standards for the same plate thickness. Another comparison is that for the 50 mm plate, Grade '350' has become Grade '295' with use of an overseas standard material.

So what should be done at the design stage? Where possible, the Design Engineer should obtain guidance from the Owner or Contractor on where the fabrication is likely to be carried out, and what materials are likely to be used.

Once the likely materials of construction are known, undertake the design to the relevant mechanical properties of the materials.

Some may challenge this approach by stating that specifying materials to AS/NZS Standards is all their design responsibility requires. They are potentially justified in this approach as the Designer, however, once the technical queries start rolling in on material substitutions, design costs can escalate rapidly, and delay projects.

A subsequent consequence of using substitute overseas standards materials is that the original design thickness (to an AS/NZS Standard) often requires substitution with a thicker plate, resulting in weight changes, drawn details no longer being accurate and potential cost penalties with these issues.

There are large savings to be made by use of selected overseas material standards for use, *at the design stage.* If AS/NZS Standard steels are then selected for fabrication, the substitution process is simple, as mechanical properties will likely exceed the design requirements.

The Design Engineer may specify further testing requirements for the use of overseas standard materials.

Whatever the materials used in design, it is imperative to state in the steelwork specifications, on drawings and in drawing notes the *Standard and the Grade* of steel specified, plus include a note that material substitution is permissible only with the approval of the *Design Engineer.*

As evident from above, be cautious with the frequently abused term 'Grade 350 steel', including when purchasing steel from Australian steel merchants.

Welding and weldability

Welding procedure qualifications can become an issue with materials (and materials substitution) manufactured to overseas standards.

At the design level, the design standards AS 4100[4] and AS 3990[5] only cover AS/NZS Standard materials.

At the welding level, AS/NZS 1554[6] also only covers AS/NZS Standard materials. Being structures, it is expected that welding will be specified to be category 'SP' in accordance with AS/NZS 1554.1 on the welding of steel structures.

So how is a welding procedure qualified in this situation? The same way one would be done in accordance with AS/NZS 1554 (and most other international welding standards) – qualification by testing, *on the materials of construction.*

Weldability of the materials of construction should also be addressed. A specific example of material substitution encountered in recent times has the following characteristics:

Design material: AS 3678 Grade 350, material thickness 10 mm, which requires a minimum yield of 360 MPa.

Fabrication material: GB/T 1591 Grade Q345C, material thickness 10 mm, which requires a minimum yield of 345 MPa.

To account for the difference in specified yield strength for the design and the material intended to be used, the Contractor proposed a material testing regime. The yield strength determined by mechanical tests provided a result on 465 MPa.

Now the initial perception is that the material easily accommodates the design, which it does on *one criterion.*

This one test to determine the suitability of the steel raises the following questions:

a) Were the testing techniques and sampling levels satisfactory?
b) Is the steel now outside the parameters of steels covered by AS 4100 or AS 3990, which limits design to materials with a yield strength of 450 MPa or less?
c) Are welding procedure qualifications affected – with an actual yield of 465 MPa is AS/NZS 1554.1 still applicable? (Qualified WPS to the Q345 material technically allows welding of materials up to 50 MPa greater, but this particular piece of steel was greater by 120 MPa.)
d) What quality control processes does the steel manufacturer have in place? (i.e. why sell a steel with 120 MPa greater strength than required?).
e) How is the toughness and ductility of the steel to be assessed?

The above issues could have been resolved at the design stage, by using the material of construction in the design calculations. Sample steel testing should then also look at rejecting excessive strength materials due to the above issues, including possibly finding another steel mill for supply!

A key principLE here is that an Australian fabricator would likely have materials testing and qualified welding procedures in place, for AS/NZS 1554.1 and the associated steel standards. If this is not the case, fabricator competency must be questioned.

Also, materials sourced overseas should be checked by the designer to ensure they satisfy the design requirements.

Maintenance issues

Very little thought is currently being given to structural maintenance requirements on steel fabricated with materials to an overseas standard.

How is structural maintenance to be carried out on materials manufactured to an overseas standard material? Do welding procedures performed to AS/NZS Standard materials remain qualified? What is the material being welded? Were WPSs retained from fabrication such that they can be used for future maintenance?

In the future, the failure to understand the above issues may result in 'repairs' being detrimental to structural integrity. Today's gains in economy may be transferring engineering to a later date?

All the above principles apply to local fabrication as well, which may use materials manufactured to an overseas standard.

Lastly, Lead Engineers in design offices need to educate and direct younger engineers to know more about steel than the AS 4100 reference to steel standards.

Editor's Note:

With steel being a global commodity manufactured largely to International, European and American standards the sole focus on Australian Steel Standards by AS 4100 and AS/NZS 1554.1 now needs to re-addressed to face these issues.

References

1. AS/NZS 3678:2011 Structural steel – Hot-rolled plates, floorplates and slabs
2. AS/NZS 3679.1:2010 Structural steel – Hot-rolled bars and sections
3. AS/NZS 1163:2009 Cold-formed structural steel hollow sections
4. AS 4100-1998 Steel structures
5. AS 3990-1993 Mechanical equipment – Steelwork
6. AS/NZS 1554 Structural steel welding