Basis for and Implications of Key Changes to 2016 Structural Steel Product Standards

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Introduction

In April 2016, the suite of AS/NZS structural steel product standards were republished (AS/NZS 1163, 3678, 3679.1-2) (SA/NZS, 2016). This paper provides a summary of the key changes, the basis for these changes and interim recommendations until full supply of steel products to the latest standard is available.

Background

The Steel Structures Standard (NZS 3404.1, SNZ, 1997) is the document cited in the Building Code for the design and construction of steel structures in New Zealand. In this standard, steel grades that are compatible with the design assumptions of this document are specified. This includes structural steels manufactured to AS/NZS, JIS and EN standards.

In New Zealand, there is no recognised approach for adopting revised versions of secondary standards referenced in documents cited in the Verification Method Document VM/B1 (MBIE, 2014). Changes to manufacturing standards can take 1 to 2 years to implement, depending on the nature of the revisions. This transition period is required to allow steel mills time to make changes to manufacturing processes, and for steel importers to destock structural steels manufactured to the previous revision of the structural steel standards.

Overview of Changes

There are a number changes to these standards, many are editorial in nature. Of the technical changes, the key ones can be summarised as follows:

1. Chemical Composition
   a. Boron (AS/NZS 1163, 3678, 3679.1)
   b. Silicon (AS/NZS 1163)
   c. Sulphur (AS/NZS 3678)
2. Product Conformity
   a. Initial Type Testing
   b. Factory Production Control

The back ground and implications of these revisions are discussed in the following section. A fact sheet summarising the changes is appended (appendix A).

Technical Basis for Changes

<u>1. Chemical Composition</u>

a. Boron

Introduction

Structural steels with elevated boron content have been reported in Australia and New Zealand in the past few years (Karpenko et al., 2016). While alloying steels with boron can have a beneficial effect on the properties of steels, such as improving surface hardness, boron has not traditionally been added to structural steels. Consequently, there has been no attempt in past revisions of the AS/NZS suite of structural steel standards to specifically regulate the practice of alloying structural steels with boron.

It is understood the primary drivers for this alloying practice are commercial rather than technical. By adding boron in sufficient quantity, the steels may be reclassified as alloyed steels to access tax concessions and to circumvent trade measures (Syam and Ng, 2016). However, having said this, boron is a necessary element within Quench and Tempered steels to AS 3597 (SA, 2008), but this is outside the scope of the present paper.

Technical Background

Additional information on the metallurgical impact of adding boron can be found in published articles/papers (Syam and Ng, 2016, Dunne, 2016). The primary concern from a safety perspective is the weldability of steels with elevated boron content (>8 PPM ie 0.0008%). The welding requirements of AS/NZS 1554.1 (SA/SNZ, 2014) have been established without considering the effects of boron as an alloying element (Karpenko et al., 2016).

Concerns over the weldability of such steels have led to the HERA Welding Centre issuing a practice note on this matter in 2016, which was reproduced as a SCNZ Steel Advisor article (Karpenko et al., 2016).

It is believed the practice of alloying steels is limited to plate and structural hollow sections from low cost Asian countries. Fortunately, when boron is intentionally added, the plate or tube mill will typically report the boron content on the mill certificate even though it is not required in the manufacturing standard. This is to demonstrate they have produced an alloyed steel, the commercial reasons for this practice have been discussed previously.

Standards Approach - Steels with Elevated Boron Content

Unfortunately, due to the vagaries of the standards committee process, there has not been a uniform treatment of this issue across the suite of AS/NZS structural steel standards.

The requirements in the 2016 revisions with respect to boron can be summarised as follows:

AS/NZS 1163: 2016	AS/NZS 3678: 2016 and AS/NZS 3679.1:2016
• No limit on the boron content • No prohibition on adding boron • Boron must be reported on the test certificate	• No limit on the boron content • Boron must not be added intentionally without the agreement of the purchaser • Boron must be reported on the test certificate

Recommended Practice

The HERA Welding Centre has recommended the following approach for welding steels with elevated boron content:

- The boron content of the steel should be reported on the mill certificate or determined by third party testing in New Zealand. Appropriate measurement techniques are discussed in (Karpenko et al., 2016).
- If the boron content is above 0.0008% by weight, the steel should be treated as non-prequalified as per AS/NZS 1554.1 (SA/NZS, 2014). This includes an additional butt weld test to verify properties of the heat affected zone.

b. Silicon

Introduction

Silicon is used as a killing agent to deoxidise steel. Higher silicon content in structural steel can have a negative impact on the embrittlement of the highly cold worked corners of cold-formed RHS sections subject to the heat from the seam welding process, as well as the galvanizing process.

Technical Background

International literature has noted that there is a higher risk of cracking in the highly cold formed corners of RHS subject to galvanizing or welding; particularly, if the steel is silicon only killed (CIDECT, 2013; ISO, 2013). Such corner cracking is averted by manufacturers by avoiding tight corner radii and by ensuring the steel is aluminium killed (CIDECT, 2009). ISO 14346 – Static Design Procedures for Welded Hollow Section Joints, Recommendations (ISO, 2013), suggests bend radii to thickness ratios for aluminium killed steels that meet various chemical composition requirements. No limit is given for the silicon content. The main recommendations with respect to welding (manufactured seam welds) in the cold formed corner regions are:

- If the bend radii and material chemistry of fully aluminium killed steels meet those recommended in the standard, the distance from the weld seam to the tangent to the inner radius should be at least 2t, where t is the wall thickness, see Figure 1.
- If the recommended bend radii and material chemistry requirements are not meet, the 2t weld seam location should be increased to 5t.

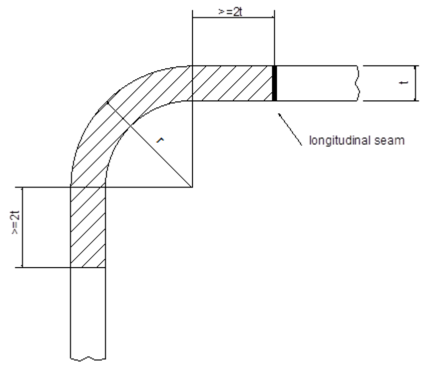

Figure 1: Weld seam location requirement

Higher silicon content will also impact on the appearance and thickness of the zinc coating for galvanized hollow sections. Above 0.24% silicon content, the appearance of the galvanizing will be duller and, due to increased reactivity, the zinc coating will be thicker. A thicker coating will result in greater durability. However, there is also the potential for the zinc coating to become brittle and flake off it becomes too thick.

Silicon Content of Structural Hollow Sections to AS/NZS 1163: 2016

In AS/NZS 1163: 2016, the silicon content for some grades of steel and section type have been reduced. The following is a summary of the silicon limits in AS/NZS 1163: 2009 compared with those given in the 2016 edition.

Section Type	AS/NZS 1163: 2009	AS/NZS 1163: 2016
Grade 250	0.05%	0.05%
Grade 350/450*	0.45%	0.25%
CHS Grade 450*	0.45%	0.45%

The basis for the reduced limit for grade 350 CHS sections is not apparent as the CIDECT and ISO 14346 documents (which were the technical basis for the reduced silicon content limits) only apply to RHS/SHS sections with tight corner radius. Higher strength steels will tend to be more prone to weldability issues. This is not reflected in the 2016 revision with the silicon limit for all grade 350 steels reduced to 0.25%, while the limit for CHS grade 450 steel has remained at 0.45%.

The limits in the 2016 edition of AS/NZS 1163 are lower than for steels manufactured to another comparable international standard EN 10219 (CEN: 2006). This standard allows for the silicon content to range from 0.4-0.6% depending on the feed stock material's characteristics.

Recommended Practice

If engineers do have concerns about the use of structural hollow sections to this earlier revision of the standard, the following steps are suggested:

Step 1 Review silicon content

Check the silicon content reported on the test certificate. If the silicon content by weight is greater than the limits in AS/NZS 1163: 2016 follow steps 2 and 3 (as applicable), otherwise no further action is recommended. Note some tube makers use aluminium killed feedstock material. Such steels will likely meet the AS/NZS 1163: 2016 silicon limits even if they are still manufacturing to the earlier standard.

Step 2 Welding

CHS Sections

If the section is to be galvanized, go to step 3, otherwise no further action is recommended.

SHS/RHS Sections

The designer may, on a case-by-case basis, consider the following risk-based approach to managing the higher risk of cracking due to seam welding in the cold worked corner regions, if the silicon content is greater than the appropriate limit in AS/NZS 1163:2016:

Importance level 2 structure

1. Check weld seam location. If it is less than 5t from the corner radius, a 100% visual inspection of the weld seam should be undertaken. Based on limited inspections of structural hollow sections used in New Zealand projects, this requirement will likely be met in many instances.
2. If attachments are welded in the corner zones of RHS/SHS sections, undertake 100% visual inspection of the heat affected zone

Importance level 3 structure

Supplement the approach recommended for importance level 2 structures with a limited extent of magnetic particle testing (<10%).

Step 3 Galvanising CHS/RHS/SHS sections

Seek advice from a galvanizer where aesthetics are important, or if there is concern that the zinc coating will become brittle and flake off.

Sulphur

Background

The properties of steel perpendicular to the plane of the element (often termed Z-properties) are different to those in plane (BSCA et al., 2017).

The production process is such that inclusions or discontinuities are rolled out to be planar and parallel to the surface of the plate. The result is that the mechanical properties in the through-thickness direction are more susceptible to the influence of these inclusions or discontinuities.

One of the ways of controlling the through-thickness properties of the steel is to limit the impurities, principally sulphur that lead to the presence of inclusions with low melting point in the steel (BCSA, 2009).

In most applications, the principal load is in the lengthwise direction. Occasionally there are situations, such as heavily welded cruciform type joints (Figure 2) where the loading is in the transverse direction. When the weld shrinks on cooling, the locally imposed strains can reach yield. When this occurs, the parent material must be adequately ductile in the through-thickness direction to redistribute these strains (BCSA, 2009).

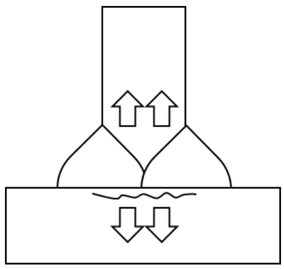

Figure 2: Example of joint subject to through-thickness strain

The impact of such imperfections on the through-thickness properties is assessed by carrying out through-thickness testing. These tensile tests categorise the through-thickness ductility of steel into three categories (Z15, Z25, Z35). The Z designation refers to the test direction, while the numerical value indicates the minimum percentage reduction in area at failure of the test sample.

Sulphur Content - AS/NZS 3678:2016

Reflecting the significance of sulphur in controlling the through-thickness properties, the sulphur content for Z25 and Z35 steels have been reduced. The following is a summary of the sulphur limits in AS/NZS 3678: 2011 and 2016.

Steel Through-thickness Designation	Sulphur Content	
	AS/NZS 3678: 2011 (%)	AS/NZS 3678: 2016 (%)
Z25	0.03	0.008
Z35	0.03	0.005

The minimum thicknesses of plate covered by through-thickness tested grades has been decreased from 16mm to 12mm in the 2016 revision.

Recommendation

AS/NZS 3678 requires the mill to undertake 1 through thickness test per batch of steel. This can represent up to 70 tonnes of steel. Where Z25 or Z35 steel is specified, it is recommended that through-thickness testing is carried out on each sheet of plate as the distribution of impurities that can lead to reduced ductility in the through-thickness direction are not distributed evenly throughout the steel.

The selection of the required design Z-value for steel should follow the approach of Appendix H, AS/NZS 1554.1:2014. The assessment should be performed in collaboration with the fabricator as weld joint details and welding techniques may have a profound effect on design Z-value.

2.0 Product Conformity

Introduction

In keeping with international practice, normative initial type testing and factory production control provisions have been introduced. These activities are defined as (Hicks, 2016):

Initial Type Testing (ITT): The complete set of tests and inspections described in the standard to determine the characteristics of samples of products representative of the product type. The ITT provides the manufacturer with the characteristics of their product using their Quality Management System (QMS) and needs to be undertaken before a product is placed on the market.

Factory Production Control (FPC): The permanent control of production exercised by the manufacturer, which provides a means by which a manufacturer ensures that the performance declared by them (obtained on the basis of ITT) continues to be valid for subsequent products. This generally involves ensuring that subsequent products remain substantially the same as those submitted to ITT (ie having same characteristics).

Standards Australia and Standards New Zealand adopt the neutrality principle, in that the conformity assessment may be undertaken by a first-party (manufacturer), second-party (the purchaser) or a third-party (independent).

Implications of Change

It is likely many of the mills supplying the New Zealand would meet the FPC requirements of the 2016 structural steel standards. Over 70% by volume of the structural steel supplied to the New Zealand market is certified under a recognised product certification scheme, such as the Australasian Certification Authority for Reinforcing and Structural Steels (ACRS, 2016). This includes mills manufacturing Hot Rolled Bars and Sections (AS/NZS 3679.1: BlueScope, Hyundai Steel, OneSteel, Rizhao Steel Holding Group, Siam Yamato Steel, Tung Ho), plate mills (AS/NZS 3678: BlueScope, Hyundai Steel, New Zealand Steel) and tube mills (AS/NZS 1163: Australian Pipe and Tube, Australian Tube Mills, New Zealand Steel, Nippon Steel and Sumikin Metal Products and Orrcon Manufacturing). A requirement of ACRS certification is that the mill must operate an effective factory production control system. Initial type testing is only relevant for mills producing a new grade of steel. If a mill has been manufacturing structural steel products to any of the AS/NZS structural steels for a period of time, they would have already established the characteristics of their product through production inspection and testing. It should be noted, however, that currently ACRS is limited to certifying products at the 'gate' of the mill, so there may be a risk of product substitution. Although the ACRS scheme rules permit distributors to also be certified to enable a 'chain of custody' to be established between the mill and the final construction site, this is currently not in place.

Conclusions

The significant changes to the 2016 editions of the AS/NZS structural steel standards and the basis for these changes have been discussed. It is anticipated it will take until the beginning of 2018 before all product supplied to the local market will be manufactured to the latest revisions of the steel product standards. In this transition period, steels manufactured to the old versions of the standards will continue to be fit for purpose for use in building and infrastructure projects designed to NZS 3404.1.

One issue not addressed adequately by the standards is the welding of steels with elevated boron content (>0.0008%). When such steels are encountered, the HERA Welding Centre practice note recommendations should be adhered to.

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Appendix A

Fact Sheet

Changes to AS/NZS steel product standards 2016

AS/NZS 1163:2016

a) Requirements for type testing and minimum production testing and inspections have been included in the normative Appendix on product conformity.
b) Test Certificates are required to be available for all products produced to this Standard.
c) Alignment of definitions associated with test unit, test product, test sample, test specimen and test piece as noted in ISO 404, AS/NZS 3678, AS.NZS 3679.1 and AS/NZS 3679.2.
d) Inclusion of notations and additional definitions in Section 3.
e) The inclusion of cold-rolled and annealed coil with hot-rolled coil for steel feed.
f) Revision to the chemical composition part of the Standard, which includes a new set of limits for finished product analysis. (eg for C350, C450 steels: Si chemical composition reduced to 0.25% maximum. For C450 CHS the limit remains at 0.45%).
g) Provision for suitability for zinc coating have been moved to the Appendix on purchasing guidelines.
h) Reformatting of the freedom from defects and testing provisions of the Standard.
i) Inclusion of the provision for individual length markings for New Zealand.
j) Minor revision to test and inspection certificates.
k) A new Appendix on formulae for calculating cross-section properties.
l) Definitions, clause numbering and layout across the four steel-product Standards AS/NZS 1163, AS/NZS 3678, AS/NZS 3679.1, and AS/NZS 3679.2 are consistent wherever possible.

AS/NZS 3679.1:2016

a) Requirements for type testing, and minimum production testing and inspections, have been included in the normative appendix on product conformity.
b) Test certificates are required to be available for all products produced to this Standard.
c) Labelling requirements have been added to enable products compliant with this Standard to be traceable back to its corresponding test certificate.
d) The prescriptive requirement of a rolled in mark on hot rolled sections greater than 150mm has been replaced by a performance based requirement that provides the same level of permanency in identification.
e) Definitions, clause numbering and layout across the four steel-product Standards AS/NZS 1163, AS/NZS 3678, AS/NZS 3679.1, and AS/NZS 3679.2 are consistent wherever possible.

AS/NZS 3678:2016

a) Requirements for type testing and minimum production testing and inspections have been included in the normative appendix on product conformity.
b) Test certificates are required to be available for all products produced to this Standard.
c) Labelling requirements have been added to enable products compliant with this standard to be traceable back to their corresponding test certificate.
d) Definitions, clause numbering and layout across the four steel-product Standards AS/NZS 1163, AS/NZS 3678, AS/NZS 3679.1 and AS/NZS 3679.2 are consistent, wherever practicable.
e) Additional definitions in Clause 3.
f) Notation clause removed as duplicated in document. All notation defined in line.
g) Sulphur limits for some Z grades (Z25 grades – sulphur 0.008% max.; Z35 grades – sulphur 0.005% max.).
h) Internal soundness clause added.
i) Tensile test dimensions defined.

j) Through-thickness tested grades down to 12 mm thickness
k) Mechanically tested grades up to 200 mm thickness
l) L0 impact tested grades have been reintroduced.
m) 'None' impact designation has been removed.
n) Option of zinc coating classification referring to AS/NZS 2312.2, Clause 9.1.