GUIDELINES FOR DESIGNING TO AS 4100 WHEN IMPORTED MATERIALS ARE INVOLVED

INTRODUCTION

The goal of the Building Code of Australia (BCA) is to achieve and maintain minimum standards of structural safety, health, fire safety, amenity and sustainability for the benefit of the Australian community now and in the future. The BCA sets out the technical requirements for building design professionals to meet in order to achieve these goals.

The BCA calls up AS 4100 “Steel Structures” as the only complying standard for the design of structural steel in buildings in Section B Part B1 of the BCA. No other Australian or overseas standard is specified for this purpose. The guidelines in this Technical Note are intended to allow structural engineers to assess the risks and a method of proceeding when designing structural steel members and connections in accordance with AS 4100 where imported materials are involved.

BACKGROUND TO AS 4100 PROVISIONS ON MATERIALS

Clause C2.2 of the Commentary to AS 4100 (AS 4100 Supplement 1—1999) states:

> *‘C2.2 STRUCTURAL STEEL*
>
> *The Standard has been written around the range of structural steels manufactured in Australia to the Australian Standards quoted in Clause 2.2.1. The Standards quoted are product type Standards.’*

Therefore, the assumption central to AS 4100 is that all steel is manufactured in accordance with the Standards quoted in Clause 2.2.1 of AS 4100 in all respects. That is what a test certificate from a steel manufacturer is intended to warrant when it is supplied. AS 4100 relies on guaranteed values of chemical composition, mechanical properties, dimensional tolerances and methods of manufacture as specified in the nominated standards AS/NZS 1163, AS/NZS 1594, AS/NZS 3678, AS/NZS 3679.1, AS/NZS 3679.2 and AS 3597.

The member design Sections (5, 6, 7, 8) of AS 4100 use general expressions for steel member capacity applicable over a wide range of steels, provided that the yield stress used in design does not exceed the value of 690 MPa nominated in Clause 1.1.1(b) of AS 4100. The design provisions in these Sections were developed for the known properties and behaviour of Australian steels which comply with the above Standards.

The capacity factors nominated in Table 3.4 of AS 4100 were derived using statistical analysis of results from steel testing of material complying with the Standards listed in Clause 2.2.1 of AS 4100 using the normal distribution curves obtained from the manufacturers as at the date of preparation of AS 4100. References cited in the Commentary to AS 4100 describe in detail how the capacity factors were derived for different member types and design actions. The capacity factors are related to the design expressions used in AS 4100 for the various nominal design capacities. The Commentary to AS 4100 advises that (see C3.4 on page 13 of AS 4100 Supplement 1—1999):

"The capacity factor takes the following into account:

(i) The probability of understrength members or connections due to variations in material strength, material properties, sizes of members and connection elements, and homogeneity.

(ii) The differences between the strengths in tests of isolated members, connections, or test pieces and the strength of the member in the structure.

(iii) The inaccuracies in the design equations related to member or connection design and inadequacies in our understanding of member and connection behaviour.

(iv) The degree of ductility and reliability required of the member or connection element under the action effects being considered.

(v) The accidental eccentricities in columns, beams and connections.

The Standard is arranged on the basis of member-by-member or connection element design. The design clauses for each member or connection element are formulated to give the best possible estimates of the nominal capacity of the member or connection element taking into account the conflicting requirements of accuracy and simplicity.

The capacity factors were derived by a process called 'code calibration' through the use of a 'safety index'. The safety index is a convenient measure of the notional safety taking into account the variabilities of the loads and the structural capacities. From a consideration of the values of safety indices for past successful designs to earlier Codes, values of target safety indices were chosen for the Standard. The capacity factors were then selected so that for designs to be standard, the associated safety indices are close to the chosen target values."

It is essential to understand that the quality of the steel and its guaranteed mechanical properties and the distribution of those properties over a period of time are the basis on which the capacity factors of AS 4100 have been derived. Steels not complying with the Standards listed in AS 4100 may not have the same distribution of mechanical properties as those steels which do comply and hence may require the use of different capacity factors to those listed in Table 3.4 of AS 4100. The capacity factors are also related to the fabrication and erection tolerances in Sections 14 and 15 of AS 4100.

Likewise, Section 9 of AS 4100 dealing with design of connection elements such as bolts, welds and connection components is based on design expressions and capacity factors that are directly related to the bolt / nut / washer standards specified in Clause 2.3.1 of AS 4100 and the welding consumables / deposited weld metals specified in AS/NZS 1554. The relevant capacity factors for bolts and welds were also derived using a statistical analysis of test results obtained from complying bolt material and welding consumables, used with steels that comply with the Australian Standards listed in Clause 2.2.1 of AS 4100.

There is also the question of weldability and brittle fracture to consider. If the steel does not comply with a Standard nominated in AS/NZS 1554, which is specified in AS 4100 as the relevant welding Standard, then Clause 2.1 of AS/NZS 1554.1 specifically requires that either:

1. *testing of the material to determine compliance with any of the grade types in the Standards nominated ..... has been carried out to the satisfaction of the Principal;*
2. *a comparison of supplied test certificates with the requirements of any of the grade types in the Standards nominated ..... has been performed to the satisfaction of the Principal.*

Since AS 4100 calls up AS/NZS 1554 as the suite of welding standards which must be met, this means than any evaluation of the steel must consider the chemical properties in order that the steel may be assigned the correct weld group number for use with AS/NZS 1554 in selecting welding consumables and for use with Section 10 of AS 4100.

When either steel materials or welding consumables are not in conformity with the nominated Australian Standards, prequalification of welding consumables is not possible and special welding qualification tests are required to be undertaken using the methods specified in AS/NZS 1554.

In summary, AS 4100 relies on guaranteed values for chemical composition, mechanical properties, tolerances on dimensions, method of manufacture and quality control provisions for all material used in a steel structure designed to AS 4100. There is a statistical relationship between the capacity factors used to determine design capacities and the test data reflected in the Australian Standards nominated in AS 4100, Section 2 and the AS/NZS 1554 suite of welding standards.

Although many of the design rules are similar to those in equivalent codes in other countries, the capacity factors are directly related to Australian steels produced to the Standards quoted in Clause 2.2.1 of AS 4100, as are other design provisions such as weldability (AS/NZS 1554), brittle fracture (Section 10 of AS 4100 and AS/NZS 1554), behaviour in fire (Section 12 of AS 4100) and behaviour under seismic loading (Section 13 of AS 4100).

ACCEPTANCE OF STEEL IN AS 4100

Clause 2.2.2 of the 1990 and 1998 editions of AS 4100 states that “Certified mill test reports, or test certificates issued by the mill, shall constitute sufficient evidence of compliance with the Standards referred to in this Standard”. Hence, such certificates should be sought when seeking to obtain evidence of compliance.

AS/NZS 1163, AS/NZS 3678, AS/NZS 3679.1 and AS/NZS 3679.2 all now have enhanced requirements for certificates which can be summarised as follows:

—written in English alphanumeric characters

—issued by the steel manufacturer

—contain the manufacturers and suppliers and testing authority names

—test certificate number and date

—product testing specification and grade of steel (e.g. AS/NZS 3679.1, 300 Grade)

—product designation and all relevant dimensions

—product steelmaking process (e.g. Basic Oxygen—Slab cast)

—length, bundle, pack or unique identifier to which test certificate applies

—heat number (from casting)

—mechanical properties from tensile tests (all values cited in AS or AS/NZS Standard)

—whether each measured mechanical property complies with Australian Standard

—chemical analysis results and type of analysis undertaken (e.g. cast analysis L or P)

Clause 2.2.2 of AS 4100 was amended in the 2012 Amendment to align better with the requirements of the material standards listed above so that it now requires the following:

> “Test reports or test certificates that comply with the minimum requirements of the appropriate Standard listed in Clause 2.2.1 shall constitute sufficient evidence of compliance of the steel with the Standards listed in Clause 2.2.1. The test reports or test certificates shall be provided by the manufacturer or an independent laboratory accredited by signatories to the International Laboratory Accreditation Corporation (Mutual Recognition Arrangement) (ILAC (MRA)) or the Asia Pacific Laboratory Accreditation Cooperation (APLAC) on behalf of the manufacturer. In the event of a dispute as to the compliance of the steel with any of the Standards listed in Clause 2.2.1, the reference testing shall be carried out by independent laboratories accredited by signatories to ILAC (MRA) or APLAC.”

Note that test reports or test certificates must be related to a specific heat number which in turn must be able to be related to a specific product. Such test reports/certificates cannot be used to change the grade of the steel—only the steel manufacturer can decide the grade of steel, as all grades of steel will have a normal distribution of test results and a single test result is simply one result in many thousands that make up the distribution.

The steel grade used in design must be the grade shown on the test report or test certificate. The design engineer needs to be satisfied as to the veracity of the information received and may consider it necessary to contact the certifying organisation to check the veracity if in any doubt.

IMPORTED MATERIAL

Imported material may be either:

(a) material manufactured overseas and claiming to comply with one of the Australian Standards cited in Clause 2.2.1 of AS 4100;

(b) material manufactured overseas and claiming to comply with one or more overseas standard(s).

For type (a) material, Clause 2.2.2 of AS 4100 applies and a certificate complying with the nominated standard should be available in order to indicate full compliance. The remainder of this Technical Note deals with type (b) material.

IMPORTED MATERIAL NOT COMPLYING WITH AUSTRALIAN STANDARDS

For material (steel sections, steel plate, bolts, welding consumables) not manufactured in Australia to Australian Standards specified in Section 2 of AS 4100, Clause 1.5.1 of AS 4100 provides a method whereby such material may be used as "new material". The Commentary to this Clause (Cl.5) in AS 4100 Supplement 1—1999 advised as follows:

> *"Standards Australia Committee BD/1, Steel Structures, is responsible for the Standard and is available to offer opinions on new materials or methods. It is usually necessary to seek approval from the appropriate building authority for the use of new materials or methods."*

Consequently, although Standards Australia may consider offering an opinion on a new material (a process likely to be very lengthy), approval from the "appropriate building authority" is also required.

The "appropriate building authority" in most States will be the nominated Building Certifier (private or government) who will have some difficulty given that he must be satisfied that any building must comply with the Building Code of Australia which nominates AS 4100 as the relevant design / fabrication / erection standard for steel buildings in Australia. Since the Building Certifier is unlikely to be fully au fait with the background to the AS 4100 provisions, convincing a Building Certifier in respect of imported materials different to those specified in Clause 2.2 of AS 4100 could be an arduous or torturous process.

The easiest way out of the difficulty of using imported material would be to design to AS 4100 and seek to ensure that the imported materials used in the design process do comply with the Standards nominated in Section 2 of AS 4100. This can be achieved by one of the following processes for the structural steel:

(1) obtain sufficient statistical data on the chemical and mechanical properties of the imported steels so that they can be assigned to one of the grades for the steels cited in Clause 2.2 of AS 4100. The logical source of data is the manufacturer but the data must be verified by way of an audit process. The volume of data required and the need to verify it may mitigate against the practical use of this method but may be warranted if significant quantities of material are involved over a period of time. Single test results are not sufficient.

OR

(2) obtain test certificates from the mill certifying that the steel intended to be used or being supplied complies with all requirements of the relevant Standard, either AS/NZS 1163, AS/NZS 1594, AS/NZS 3678, AS/NZS 3679.1, AS/NZS 3679.2 or AS 3597. Fully compliant test certificates should be provided which meet the requirements of Clause 2.2.2 of AS 4100 (2012 amendment).

The imported material should comply with all the requirements of the relevant Australian Standards in Clause 2.2 of AS 4100. The importer of the steel should be able to supply this information from the manufacturer or should supply independent verification of the information from an independent laboratory accredited by ILAC or APLAC in accordance with Clause 2.2.2. If not available, independent verification must be carried out. It should be noted that the quality and reliability of the original documentation will vary according to source and country of origin and the design engineer needs to be satisfied as to the

veracity of the information received and may consider it necessary to contact the certifying organisation to check the veracity if in any doubt. If no independent verification is available, then independent testing as in item (3) below should be sought.

The latest editions of AS/NZS 1163, AS/NZS 3678, AS/NZS 3679.1 and AS NZS 3679.2 all require ILAC (MRA) accredited laboratory certification to demonstrate compliance. This may be supplied by the manufacturer's own laboratory (if so accredited) or by an independent accredited laboratory. It would be consistent with this requirement for design engineers to request the same independent testing for imported material. In the United States and Canada, structural engineers are encouraged not to accept any imported steel for structural purposes without independent laboratory certification to their relevant standards.

OR

(3) have sufficient tests done by an independent ILAC or APLAC accredited laboratory (all Australian NATA laboratories are ILAC accredited) under Clause 2.2.2 and obtain certification from the accredited laboratory to enable the steel to be fitted into a grade in the relevant Standard in terms of all parameters in the Standards. The independent accredited laboratory should also assess the chemical composition so as to enable the steel to be allocated a weld group number in terms of AS/NZS 1554 (weldability) and Section 10 of AS 4100 (brittle fracture)

OR

(4) treat the steel as unidentified steel. As the Commentary to AS 4100 (AS 4100 Supplement 1—1999) notes:

"It is preferable that any unidentified steel should be tested in accordance with AS 1391, but if this is not possible, the Standard requires the severe assumption that a design yield stress not exceeding 170 MPa and a design tensile strength not exceeding 300 MPa be used, as appropriate. Most steels will have a yield stress and tensile strength in excess of these and testing may give a more economic result."

It should be noted that this fourth approach is not going to be economic for realistic scenarios. Also note that this option does not address the issues of the weldability of the steel or the possibility of brittle fracture occurring.

Another option would be to use a reduced capacity factor for the imported steel material. An arbitrary value should not be selected but rather it is necessary to obtain sufficient statistical data on the mechanical properties and their normal distribution just as was done for the materials listed in Section 2 of AS 4100. It is then necessary to carry out sufficient statistical studies on the available data to derive new capacity factors, yield stress and tensile strength using the approaches detailed in the references to the Commentary to AS 4100. Chemical composition will also have to be assessed to allow assignment to a weld group in AS/NZS 1554 and Section 10 of AS 4100. This process would be very lengthy, thus mitigating against its use also. The logical source of data required is the manufacturer but the data must be verified by way of an audit process.

For bolts, options (2) or (3) are the feasible options. The bolt standards specified in Clause 2.3.1 of AS 4100 specify the requirements that must be met and also specify a number of related standards that must be complied with. All requirements of all cited standards need to be complied with including product chemistry, mechanical properties, thread dimensions and properties, methods of manufacture, tolerances, dimensions. The extent of testing should comply with the requirements of the Standards. The certificates supplied should comply with Clause 2.3.1 of AS 4100 (2012 amendment), and cover all the items listed in the Appendix to ASI Technical Note TN001 Version 3.

For welding consumables, options (2) or (3) are feasible. AS/NZS 1554 suite of welding standards specifies a number of ancillary standards for welding consumables which must be complied with and these ancillary standards specify the extent of testing that must be carried out in order to ensure compliance. Welding procedure qualification of steel material, consumables, joint preparation and welding parameters should be in accordance with

AS/NZS 1554. Note that prequalified consumables in AS/NZS 1554 are all related to material to Australian Standards.

Conformity assessment by the manufacturer of the imported material under options (2) and (3) should be carried out under a recognised scheme meeting ISO/IEC Guide 28 “Conformity Assessment—Guidance on a Third Party Certification Scheme for Products” and should include details of auditing carried out. (Note: this ISO/IEC Guide has been issued as Australian Standard HB 18.28). The information should include all test / quality control checks carried out to ensure conformity and should contain sufficient information to allow traceability.

The organisation providing the certification should comply with ISO/IEC Guide 65 “General Requirements for Bodies Operating Product Certification Schemes”, issued as Australian Standard HB 18.65.

IMPORTED FABRICATED STEEL

The above discussion relates to imported material that is fabricated in Australia. When imported fabricated steelwork is used in an Australian project, another layer of complexity and documentation is introduced.

The imported material must be supported by the same level of documentation that is indicated earlier in this Technical Note, but the material in each fabricated item must be traceable back to the original documentation. This usually cannot be done by the markings on the fabricated sections as any initially present may be lost in the fabrication process as members and components are cut from raw material supplied. The overseas fabricator needs a quality system in place which identifies which piece of documentation relates to each fabricated piece. Traceability becomes a major issue.

Additionally, fabrication tolerances in AS 4100 have been considered when formulating the expressions for nominal design capacity, particularly those for straightness of flexural and compression members. Just the same as fabrication tolerances need to be checked for steel fabricated in Australia, any imported fabricated steelwork needs to have documentation to the effect that the fabrication complies with AS 4100 requirements or the fabricated steelwork will have to be measured and checked when landed in Australia.

Documentation on the welding carried out during fabrication also needs to be available, and should state that the welding has been carried out and inspected in accordance with the requirements of AS/NZS 1554 suite of welding standards.

Compliance issues relating to fabricated steel are discussed in detail in ASI Technical Note TN007 “Compliance issues and steel structures”.

CONCLUSION

There is thus no bar to the use of steel not manufactured in Australia for the design of steel members using AS 4100 if any one of the four paths identified in this Technical Note are followed. In terms of design using the provisions of AS 4100, all Australian Standards nominated in Section 2 of AS 4100 must be complied with for the reasons given earlier. Compliance with another material Standard or Specification is not acceptable nor relevant.

Imported materials must be rigorously tested, either by the manufacturer / supplier or by independent organisations, to ensure compliance with the Australian Standards nominated in Section 2 of AS 4100. Then, certificates of compliance with these Standards can be issued and design to AS 4100 can be carried out.

The onus is on the responsible design entity to ensure that all requirements of AS 4100 and standards referenced in AS 4100 are complied with. The responsible design entity can then issue a Certificate stating that design conforms to AS 4100 to the Building Certifier.

REFERENCES

Standards Australia, AS 4100, “Steel structures” (1998 edition and 2012 amendment).

Standards Australia, AS 4100 Supplement 1—1999, “Steel structures—Commentary”.

Standards Australia/Standards New Zealand, AS/NZS 1163—2009, “Cold formed structural steel hollow sections”.

Standards Australia/Standards New Zealand, AS/NZS 1554, “Structural steel welding” Part 1: “Welding of steel structures”, Part 4 “Welding of high strength quenched and tempered steels”, Part 5: “Welding of steel structures subject to high levels of fatigue loading”.

Standards Australia/Standards New Zealand, AS/NZS 3678—2011, “Hot rolled steel flat products”.

Standards Australia/Standards New Zealand, AS/NZS 3679.1—2010, “Structural steel, Part 1: Hot rolled bars and sections”.

Standards Australia/Standards New Zealand, AS/NZS 3679.2—2010, “Structural steel, Part 2: Welded I sections”.