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COMPLIANCE ISSUES AND STEEL STRUCTURES

INTRODUCTION

Compliance requires being in accordance with specified rules, specifications, policies, standards or laws.

Compliance for steel structures involves three stages:

(a) Compliance with the Building Code of Australia;

(b) Compliance with the design provisions of AS 4100 'Steel structures';

(c) Compliance with the construction provisions of AS 4100.

This Technical Note outlines the requirements involved in ensuring compliance for all three stages.

COMPLIANCE WITH THE BUILDING CODE OF AUSTRALIA (BCA)

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 a 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. Hence, for steel structures, compliance with the BCA requires compliance with AS 4100 'Steel structures'.

COMPLIANCE WITH AS 4100 AT THE DESIGN STAGE

Structural engineers are often required to issue a certificate indicating that a particular design complies with AS 4100 and therefore complies with the Building Code of Australia. The form of this certificate may be dictated by the Principal Certifying Authority or may be of a form that is decided by the structural engineer.

In issuing such a certificate, the structural engineer is warranting that the design complies in all respects with Sections 1 to 13 inclusive (as applicable) of AS 4100. This includes the fact that the materials on which the design is based comply with AS 4100.

In respect of materials, AS 4100 Section 2 specifies the materials which form part of the provisions of AS 4100. All materials nominated are covered by Standards, either Australian (AS prefix) or joint Australia/New Zealand (AS/NZS prefix).

The material Standards nominated in Section 2 of AS 4100 are as follows:

AS/NZS 1163 Structural steel hollow sections
AS/NZS 1594 Hot rolled steel flat products
AS/NZS 3678 Structural steel—Hot rolled plates, floorplates and slabs
AS/NZS 3679.1 Structural steel, Part 1: Hot rolled bars and sections
AS/NZS 3679.2 Structural steel, Part 2: Welded I sections

AS 1110 (series) ISO metric hexagon bolts and screws—Product grades A and B
AS 1111 (series) ISO metric hexagon bolts and screws—Product grade C
AS 1112 (series) ISO metric hexagon nuts
AS/NZS 1252 High strength steel bolts with associated nuts and washers for structural engineering

All welding electrodes and deposited weld are required to comply with the AS/NZS 1554 suite 'Structural steel welding' Parts 1, 2, 4 and 5.

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. AS 4100 relies on guaranteed values of chemical composition, mechanical properties, dimensional tolerances and methods of manufacture as specified in the above Standards.

The member design sections (5, 6, 7, 8) of AS 4100 use general expressions for steel member design capacity applicable over the range of steels nominated in Clause 2.2.1 of AS 4100, 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 were developed for the known properties and behaviour of Australian steels which comply with the above Standards.

The capacity factors nominated in Clause 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 the original 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.

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.

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.

In summary, AS 4100 design provisions are specifically related to materials that comply with the Standards listed in Section 2 of AS 4100. 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 is only then in a position to issue a certificate stating that design conforms to AS 4100 to the Principal Certifying Authority.

Since there are currently imported steels also being used in Australia, guidance on how design using such steels may be undertaken using the provisions of AS 4100 is discussed in a separate ASI Technical Note TN005 'Guidelines for designing to AS 4100 when imported materials are involved'. A number of possible paths are provided in TN005.

COMPLIANCE WITH AS 4100 AT THE CONSTRUCTION PHASE

Clause 1.7 of AS4100 states that:

> *'All steel structures, designed in accordance with this Standard, shall be constructed to ensure that all the requirements of the design as contained in the drawings and specification, are satisfied.'*

Structural engineers or fabricators and/or erectors may be required to issue a certificate indicating that the structure as erected complies with AS 4100 and therefore complies with the Building Code of Australia. The form of this certificate may be dictated by the Principal Certifying Authority or may be of a form that is decided by the provider of the certificate.

Compliance at the construction phase involves the following steps:

(1) Ensuring that the materials used conform to those used in design, which means that all the materials comply with Section 2 of AS 4100;

(2) Ensuring that the fabrication complies with Section 14 'Fabrication' of AS 4100;

(3) Ensuring that the erected structure complies with Section 15 'Erection' of AS 4100.

ENSURING MATERIAL COMPLIANCE

The steel material standards listed in Section 2 Clause 2.2.1 of AS 4100 all contain specific provisions which enable the purchaser or his representative to check whether the material supplied complies with the provisions of the nominated Standard.

The main features of the current editions of these steel material Standards are as follows:

(a) In-line marking at the time of manufacture which allows the product to be inspected and its provenance checked;

(b) Test certificates or reports provided on behalf of the manufacturer by a laboratory accredited to ILAC (International Laboratory Accreditation Cooperation) through their Mutual Recognition Agreement (MRA) which allows the actual test values for a heat to be compared against the requirements of the relevant Standard. A manufacturer may have its own ILAC accredited laboratory or may employ an independent laboratory.

AS 4100 Clause 2.2.2 'Acceptance of steels' states in the 1990 and 1998 editions 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'.*

AS/NZS 1163, AS/NZS 3678, AS/NZS 3679.1 and AS/NZS 3679.2 all now have enhanced requirements for test 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;
- Product designation and all relevant dimensions;
- Product steel making process;
- Length, bundle or pack or unique identifier to which the certificate applies;
- Heat number (from casting);
- Mechanical properties from tensile tests (all values cited in AS/NZS Standard);
- Whether each measured mechanical property complies with AS/NZS Standard;
- Chemical analysis results and type of analysis undertaken.

The OneSteel website www.BuildWithStandards.com.au contains details of the requirements of the above Australian Standards as well as details of the requirements for test certificates.

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 bolt Standards listed in Clause 2.3.1 of AS 4100 do not contain specific requirements for test certificates. ASI Technical Note TN001 'High strength structural bolt assemblies to AS/NZS 1252' discusses quality issues related to bolts, nuts and washers claiming to comply with AS/NZS 1252 and discusses how compliance with the Standard might be achieved and what a test certificate should contain. The principles are essentially the same as for steel material as listed above.

The 2012 Amendment to AS 4100 contains very specific provisions, as follows:

'Test certificates that state that the bolts, nuts and washers comply with all the provisions of the appropriate Standard listed in Clause 2.3.1 shall constitute sufficient evidence of compliance with the appropriate Standard. Such test reports shall be provided by the bolt manufacturer or bolt importer and shall be carried out by 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, importer or customer. In the event of a dispute as to the compliance of the bolt, nut or washer with any of the Standards listed in Clause 2.3.1, the reference testing shall be carried out by independent laboratories accredited by signatories to ILAC(MRA) or APLAC.'

ENSURING COMPLIANCE FOR FABRICATION STAGE

Section 14 'Fabrication' of AS 4100 applies to fabrication work done both in the fabrication shop and on site.

Clause 14.2.1 of AS 4100 requires that 'All material shall satisfy the requirements of the appropriate material standard specified in Clauses 2.2, 2.3 and 2.4', while Clause 14.2.2 requires that 'The steel grade shall be identifiable at all stages of fabrication ...' which can be satisfied by the in-line marking system contained in the steel material Standards referred to previously.

The initial responsibility for ensuring that the material complies with the relevant material Standard rests with the fabricator who should insist on being supplied with the compliant test reports or certificates by the steel distributor or manufacturer. If the fabricator is not certifying that the fabricated steel complies with AS 4100, then the fabricator should pass on all the material test certificates to the certifying party.

Section 14 of AS 4100 contains specific provisions for:

- When fabricated steel needs to be rejected (Clause 14.1);
- Straightening methods (Clause 14.3.1);
- Contact surfaces in full contact splices (Clause 14.3.2);
- Cutting and cut surface roughness (Clause 14.3.3);
- Welding (Clause 14.3.4);
- Holing (Clause 14.3.5);
- Bolting generally (Clause 14.3.6.1);
- Preparation of surfaces in contact in bolted connections (Clause 14.3.6.3);
- Tolerances (Clause 14.4).

The reality in the current marketplace is that reliance is usually placed on the quality system of the fabricator to guarantee that compliance with all of the above provisions of AS 4100 is achieved. If the fabricator is certifying that the fabricated steel complies with AS 4100, then it is up to the fabricator to ensure that this is so. If another party is certifying that the erected steelwork complies with AS 4100, then the fabricator should provide the relevant documentation from their quality system to the certifier.

Any documentation supplied should include details of measurements carried out to ensure that the tolerances specified in Clause 14.4 are all complied with.

Clause 14.3.4 Welding of AS 4100 refers to AS/NZS 1554.1, AS/NZS 1554.4 or AS/NZS 1554.5 as appropriate for all welding requirements and these Standards have their own set of provisions that must be met in order for the welding to be compliant. A general discussion of the requirements of AS/NZS 1554.1 is contained in the ASI publication 'Design Guide 2: Welding in steel connections'. AS/NZS 1554.4 and 1554.5 contain similar provisions.

AS/NZS 1554.1 requires that the welding procedure be qualified before welding commences and that the fabricator establish a welding procedure and list the applicable parameters on a welding procedure qualification record which must be available for inspection. Prequalified welding procedures are permitted subject to nominated provisions being complied with. If another party is certifying that the fabricated steelwork complies with AS 4100, then the fabricator should provide the relevant documentation for the welding procedure and any associated testing undertaken to the certifier.

AS/NZS 1554.1 also contains specific provisions related to the welding process including:

- Edge preparation and assembly;
- Preheat;
- Tack welds;
- Distortion and residual stress;
- Cleaning and dressing welds.

The reality in the current marketplace is that reliance is usually placed on the quality system of the fabricator to guarantee that compliance with AS/NZS 1554.1, 1554.4 or 1554.5 is achieved. If the fabricator is certifying that the welding complies with AS/NZS 1554.1, 1554.4 or 1554.5, then it is up to the fabricator to ensure that this is so. If another party is certifying that the fabricated steelwork complies with AS 4100, then the fabricator should provide the relevant documentation from their quality system regarding the welding to the certifier.

Welds are either weld category SP or GP in AS/NZS 1554.1 and each category has different inspection requirements and permissible imperfection levels. AS/NZS 1554.5 has different inspection and permissible imperfection levels for welds subject to fatigue loading. Inspections may involve one or more of the following: visual examination, magnetic particle examination, liquid penetrant examination, radiographic examination or ultrasonic examination—as specified by the structural design engineer in the design documentation.

The fabricator needs to carry out the relevant inspections using either the fabricator's own facilities or those of a specialised welding inspection service. Weld inspection reports should indicate that the welds have imperfection levels below the permissible values specified in AS/NZS 1554.1 or AS/NZS 1554.4 or AS/NZS 1554.5 as applicable for the weld category. If another party is certifying that the fabricated steelwork complies with AS 4100, then the fabricator should provide the relevant documentation for the welding inspection results to the certifier.

ENSURING COMPLIANCE FOR ERECTION STAGE

Section 15 of AS 4100 contains specific provisions for:

- When erected steel needs to be rejected (Clause 15.1);
- Contact surfaces in full contact splices (Clause 14.3.2);
- Cutting and cut surface roughness (Clause 14.3.3);
- Welding (Clause 14.3.4);
- Holing (Clause 14.3.5);
- Bolting generally (Clause 14.3.6.1);
- Preparation of surfaces in contact in bolted connections (Clause 14.3.6.3);

- Tolerances (Clause 15.3);
- Delivery, storage and handling (Clause 15.2.2);
- Assembly and alignment (Clause 15.2.3);
- Assembly of a connection involving tensioned bolts (Clause 15.2.4);
- Methods of tensioning bolts (Clause 15.2.5);
- Inspection of bolted connections (Clause 15.4);
- Grouting at supports (Clause 15.5).

The reality in the current marketplace is that reliance is usually placed on the quality system of the erector to guarantee that compliance is achieved. If the fabricator or the erector is certifying that the erected steel complies with AS 4100, then it is up to the erector to ensure that this is so. If another party is certifying that the erected steelwork complies with AS 4100, then the erector should provide the relevant documentation from their quality system to the certifier.

If a structural engineer is carrying out the construction certification, either directly for the purchaser or for the fabricator or the erector, then he may wish to carry out an independent inspection to ascertain the condition of the erected steelwork.

Any documentation supplied should include details of measurements carried out to ensure that the tolerances specified in Clause 15.3 are all complied with. This may involve an accurate survey, arranged by either the erector or the purchaser.

A significant issue is that of tensioning bolts in accordance with Clause 15.2.4 in the case of bolting categories 8.8/TB and 8.8/TF. Clause 15.2.4 permits two alternative methods of tensioning, namely the part-turn method and the direct tension indication device method, and the question arises as to the evidence of compliance that is possible with each method.

More details of the above two tensioning procedures may be found in the ASI publication ‘Design Guide 1: Bolting in structural steel connections’. Note that the torque control method is not permitted as an installation method but is permitted under Appendix K of AS 4100 in order to detect gross under-tensioning.

The part-turn method requires that location marks be placed on the bolt and the nut once snug-tightening is complete and that the nut then be turned a prescribed amount depending on the bolt length and the disposition of the outer faces of the bolted parts. Hence, a permanent record should exist of the tensioning for each bolt via the mark on the nut being rotated the requisite amount of turn. The use of a direct tension indication device (such as a load indicating washer or part of the bolt shearing off) should also leave a permanent record.

Ideally, an independent inspection in terms of Clause 15.4 of AS 4100 should be carried out to observe the permanent records left for each bolt but, if this is not done, then reliance has to be placed on the quality system records of the erector and the earlier comments about this information being supplied apply.

Any site welding should comply with Clause 14.3.4 and the comments made earlier under ‘Fabrication’.

REFERENCES

Standards Australia, AS 4100, ‘Steel structures’ (1990, 1998 editions and 2012 amendment).

Standards Australia, AS 4100 Supplement 1—1999, ‘Steel structures—Commentary’.

Australian Steel Institute, ‘Design Guide 1—Bolting in Structural Steel Connections’, 2007, Author Hogan, T.J., Contributing Author and Editor, Munter, S.A.

Australian Steel Institute, ‘Design Guide 2—Welding in Structural Steel Connections’, 2007, Author Hogan, T.J., Contributing Author and Editor, Munter, S.A.