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DOCUMENTATION OF STRUCTURAL STEEL

INTRODUCTION

Documentation of structural steel needs to be adequate to the extent that there is no ambiguity as to the requirements for a particular project, so that disputes and contract variations are minimised, requests for information are minimised and there are no problems with the fabrication and erection of the structural steel. The function of documentation is to transfer information accurately so as to provide complete understanding of what is required and to be a record of what was built. A minimum standard of documentation is required in the interests of all parties involved in a structural steel project.

The intention of this Technical Note is to provide a basic set of guidelines for what should be included in the documentation of the structural steelwork. The prime focus is on traditional documentation but consideration is also given to the implications of Building Information Modelling (BIM). Additional more detailed information may be found where required in the References cited in this Technical Note.

All documentation should have the following attributes:

(1) Accuracy;
(2) Clarity of intent;
(3) Checked thoroughly before issue in accordance with a firm's quality plan;
(4) Coordinated within the set of drawings and between drawings from others;
(5) Completeness and consistency;
(6) Contractually enforceable;
(7) Clear in the allocation of responsibility;
(8) Conforming to accepted drawing standards.

The documentation provided typically involves the following types:

(i) Architectural drawings;
(ii) Structural engineering drawings;
(iii) Specification;
(iv) Services drawings (where relevant);
(v) Shop detail drawings.

Clearly, a number of parties can be involved in the presentation of the various types of documentation and coordination between disciplines is a significant issue as a result. Increasingly, 3-dimensional models and/or BIM are being used to aid coordination between disciplines.

DRAWING STANDARDS

The relevant drawing standards for Australian use are contained in the AS 1100 suite of Standards, the main relevant Parts being AS 1100.101, AS 110.201, AS1100.301 and AS/NZS 1100.501 (see References).

ARCHITECTURAL AND SERVICES DRAWINGS

Dimensional set-out of the building and set-out of the location of all steelwork members should be clear on the architectural drawings. The use of architectural and services drawings should be viewed as a supplement to the structural engineering drawings for the purposes of defining member connectivity, supplementary details and other construction information. Generally, little or no structural engineering information is shown on the architectural drawings.

Architectural drawings should comply with AS 1100.301, while mechanical engineering drawings should comply with AS 1100.201.

A coordination check should be carried out by both architect and structural engineer to ensure that the information presented in respect of the structural steel members is fully consistent between the two sets of drawings. As noted earlier, 3-dimensional models and BIM can assist in this regard.

SHOP DETAIL DOCUMENTATION

Shop detail drawings are documents prepared specifically for the fabrication and erection processes. These drawings contain member sizes, full dimensioning of members, all associated plates and gusset details, weld sizes and hole diameters. Each steelwork piece is shown individually and allows the fabrication shop to fabricate all items of structural steelwork required. The preparation of such drawings involves the interpretation and coordination of architectural, services and structural engineering drawings and any other relevant information about the building.

Shop detailing is usually undertaken by a specialist firm once all the other documentation is available. There are however alternatives, as discussed below.

The ‘Australian Steel Detailers Handbook’ (see References) contains the fundamentals of the shop detailing of members and connections.

STRUCTURAL ENGINEERING DOCUMENTATION

Structural documentation typically involves preparation and issuing at two stages, namely:

(a) For Tender or For Pricing stage, which should contain sufficient information to enable tenderers to measure and price every structural steel member, with sufficient indicative connection details to allow labour and material inputs to be priced;

(b) For Construction stage which should be sufficiently detailed to enable the structural steel to be accurately shop detailed and the fabrication and erection stages to be properly planned. Note that this may need to include details of any necessary temporary bracing as discussed in Technical Note TN002 ‘Issues with temporary bracing of steel structures.

The usual arrangement in Australia at this time is that the structural engineer shows all member sizes and connection details to a level of detail such that shop detail drawings can be prepared and the fabrication and erection work programmes can be fully documented. Unfortunately, the level of such documentation does not always meet the level of detail considered necessary by the shop detailer, fabricator and erector and this can result in the issuance of ‘Requests for Information (RFI’s)’ to the structural engineer and/or architect. A large number of such RFI’s causes additional costs, irritation and frustration to all parties and inevitably delays to the project occur. In general, it is more economical and time efficient for the architect and structural engineer to provide documentation up-front rather than leave it to be resolved during the RFI process at a later stage. The RFI process can become so frustrating for all parties that they become frustrated with the overall steel fabrication process which leads to the perception of increased risk with steel projects.

In rare cases, the structural engineer also provides the shop details. This method of documentation can solve many of the coordination issues but is rarely used because fabricators generally prefer to choose their own shop detailers and most structural engineering firms do not have the required expertise in-house and don’t wish to acquire it.

Many overseas countries have a system whereby the structural engineer only provides framing drawings and specifies design actions at the connections, leaving the shop detailer to design and detail all the relevant connections. In effect, the shop detailer puts the structure together from the available information and this may lead to more practical and economical detailing with a commensurate saving in time and is recommended for consideration. This approach does not solve all the coordination issues but certainly reduces them considerably.

An alternative approach is for the shop detailer to be part of the design team, employed by the Principal, which means that the shop detailer has early access to details of the design as it develops. Hence, the shop detailer can commence work at an early stage, and the shop detailer can contribute suggestions during the documentation stage, so that design details are developed before the tendering and details are fully resolved for the construction stage.

The overall time frame should be reduced using this approach and better information is available for both the tender stage and the construction stage. Once the fabricator is selected, ordering and fabrication can proceed expeditiously once the shop details are finalised and a lot of the RFI issues that occur with other methods do not arise.

It is sometimes argued that this approach is more costly, but in reality, the cost is simply up-front rather than being hidden in the fabrication cost. The upfront cost is offset by a reduced fabrication cost and savings in time due to a large reduction in RFI's issued, as well as reduced cost of re-working or variations arising from RFI's or coordination issues.

STRUCTURAL ENGINEERING DRAWING REQUIREMENTS

AS 1100.101 and AS/NZS 110.501 provide the relevant requirements for structural engineering drawings of structural steelwork. These Standards set out requirements for matters such as:

(1) Dimensioning;
(2) Linework;
(3) Abbreviations;
(4) Grid numbering and cross-referencing;
(5) Drawing formats;
(6) Pen sizes.

More information may be found in Steel Construction Vol 29 No 3 (see References).

AS 4100 'Steel structures' Clause 1.6 contains specific requirements as to what should be included on structural steel drawings, as follows:

Design Data

(a) The reference number and date of the applicable design Standard;
(b) The nominal loads;
(c) The corrosion protection;
(d) The fire resistance level;
(e) The steel grades used (which should comply with Section 2 of the Standard).

Design Details

(a) The size and designation of each member;
(b) The number, sizes and categories of bolts used in the connections;
(c) The sizes, types and categories of welds used in the connections;
(d) The level of visual examination and other non-destructive examination required;
(e) The sizes of the connection components;
(f) The locations and details of planned joints, connections and splices;
(g) Any constraint on construction assumed in the design;
(h) The camber of any members;
(i) Any other requirements for fabrication, erection and operation.

AS 4100 Supplement 1 notes that "the design data and design details required to be shown on drawings are the minimum information that need to be provided to ensure adequate documentation".

Due to Amendment 1 of 2012 to AS 4100-1998, in respect of welds, structural engineers will have to clearly identify on the structural drawings and in the specification both the weld size, the weld category and the nominal tensile strength of the weld metal as selected from Table 9.7.3.10(1) of AS 4100. Since there are now a number of different electrode designations involved for each welding process and a number of potential welding processes and since the selection of the welding process to be used should be left to the fabricator, specifying the tensile strength of the weld metal on the structural drawings is what is now recommended to be done. The previous method of specifying an electrode designation won't work with the new multiple electrode designations. For more information, refer to Technical Note TN008 'Welding consumables and design of welds in AS 4100-1998 with Amendment 1 2012'.

One of the main complaints from shop detailers are that only typical details are often shown on structural drawings. Clearly, the requirements of AS 4100 mean that more than typical connections need to be shown, and that non-typical details are also required to be documented.

The AS/NZS 1554 suite of Standards also contains requirements for 'drawings or other documents that give details of welded connections', the requirements contained in AS/NZS 1554.1 being as follows:

(a) Specification of grade of parent metal;
(b) Nominal tensile strength of the weld metal;
(c) Location, type, size of welds and the effective length of welds;
(d) Whether welds are to be made in the shop or on site;
(e) Weld category;
(f) Details of non-standard welds;
(g) Details of seal welds, if such welds are required;
(h) Type and extent of inspection, including any special inspection requirements;
(i) Relevant design Standard;
(j) Any special requirements that could affect welding operation.

There is some overlap between the requirements of AS 4100 and the AS/NZS 1554 suite of Standards, but clearly a considerable amount of information is required to be provided for compliance with these Standards.

Steel Construction New Zealand has published a 'Code of practice for structural steelwork documentation' which sets out recommended requirements for documentation. ASI is investigating producing an equivalent document for Australian conditions.

The draft 'Code of Practice - Safe design of structures' produced by Safe Work Australia requires 'designers to give adequate information to each person who is provided with the design' and requires a Safety Report that 'specifies the hazards relating to the design of the structure… that create a risk to persons who are to carry out the work'. Thus, additional information to that listed above may well be required.

IMPLICATIONS OF INADEQUATE DOCUMENTATION

The implications of inadequate documentation have been canvassed by a number of authors in three Steel Construction Journal articles published by the Australian Steel Institute (see References for details). The main implications listed in those sources are as follows:

(1) Inefficiency in the overall construction process;
(2) Increased construction and contractual risk;
(3) Increased risk of litigation;
(4) Increased costs to all parties;
(5) Increased risk of lower quality in the final construction;
(6) Time delays as matters in dispute are resolved via requests for information;
(7) Increased contractual disputes;
(8) Increased re-work.

The common complaints about documentation are also canvassed by the authors in the same three Steel Construction Journals and can be summarised as follows:

(1) Missing details particularly for difficult details;
(2) Conflicting details and lack of coordination;
(3) Erroneous cross-referencing;
(4) Impractical details;
(5) Non-use of standard details;
(6) Straight-out errors.

SUGGESTED BASIC CHECKLIST FOR STRUCTURAL DRAWINGS

FRAMING PLANS, ELEVATIONS AND SECTIONS

- Plans, elevations and sections sufficient to enable the building profile to be understood. Typically this would involve plan at each typical and non-typical level, an elevation of each wall, typical and non-typical cross-sections;
- Every member identified with a distinguishing mark related back to a member schedule which identifies the member size, grade of steel, camber or any other relevant information;
- A set of relevant notes such as those shown in the Appendix to this Technical Note;
- Location of any expansion joints, member splices, member camber if any, inclination if any;
- Location and member sizes for any bracing;
- Purlins and girts should be shown on the relevant roof plans and wall elevations or separate purlin plans/girt elevations produced;
- Purlin and girt details such as member size, maximum spacing, any lap lengths and lap locations, bridging requirements, any trimmer members on gables, hips, valleys and roof openings;
- Any relevant reference levels or heights;
- Door or opening framing;
- Fascia elevations/framing.

STRUCTURAL STEEL DETAIL DRAWINGS

- A set of relevant notes such as those shown in the Appendix to this Technical Note;
- On many projects, a set of standard connection details could normally cover a large percentage of the connections involved. Standardised connections complete with all required connection elements and design capacity tables are contained in the Design Guides for simple and rigid connections produced by the Australian Steel Institute. Alternatively, firms can produce their own set of standard details by creating a library of such details;
- The ASI Design Guides have standardised details for web side plate connections (DG3), flexible end plate connections (DG4), angle cleat connections (DG5), cover plate splice connections (DG12), bolted moment end plate connections (DG10 and DG12) and welded moment connections (DG11). These can all be specified with a typical detail and a relevant text description;
- Other details that can be standardised within an organisation include: holding down bolt details, fly braces, bracing connections using angles, rods and hollow sections, purlin and girt cleats, end wall column connections, door framing details. Provide bolt details, weld details and cleat details for all such standardised details;
- Provide complete details of all non-standard connections including bolt details, weld details and cleat details;
- Any dimensioning of connections and components should only be provided where they are critical to the design or non-standard;
- Welds should be specified by performance requirement leaving the fabricator to determine the most economical method of fabrication – this especially applies to butt welds where AS/NZS 1554.1 permits a range of parameters;
- Connections to other materials such as concrete and/or masonry.

BENEFITS OF BIM (BUILDING INFORMATION MODELLING)

3-dimensional BIM has the benefit that a 3-dimensional model of a building is built up from inputs provided by all in the design team, thus solving coordination issues as the model is built up. Once the model is constructed, conventional drawings can be finalised by the various disciplines. As the use of BIM becomes more widespread, such drawings will become just a part of the overall supply of information and the issue of inadequate documentation discussed above should be significantly reduced.

In respect of structural steel, the information requirements listed above in this Technical Note will still need to appear somewhere in the documentation. A BIM Management Plan (BMP) should be drawn up which should define the form and format of deliverables such as drawings and the information identified above should become referenced in the BMP. NATSPEC have been active in creating a "National BIM Guide" and a "BIM Management Template" (refer to their website: http://bim.natspec.org). The way that BIM is supposed to interact with and share information with other systems (such as shop detailing software) is also defined in the BMP.

Templates can be set up within BIM software to define the information that is required to be placed on any 2- or 3- dimensional drawings and such templates should contain the information indicated above in this Technical Note.

REFERENCES

Standards Australia, AS 4100-1998 including Amendment 1 -2012, "Steel structures'.

Standards Australia, AS 4100 Supplement 1–1999, 'Steel structures – Commentary'.

A.A.Syam (editor), 'A Guide to the requirements for engineering drawings of structural steelwork", Australian Institute of Steel Construction, Steel Construction, Vol 29 No 3 September. 1995.

P.A.Tilley, 'Design and documentation deficiency and its impact on steel construction', Australian Institute of Steel Construction, Steel Construction, Vol 32 No 1 March 1998.

Two papers by different authors on 'Engineering documentation standards', Australian Institute of Steel Construction, Steel Construction, Vol 34 No 4 December 2000.

American Institute of Steel Construction, 'Code of standard practice for steel buildings and bridges, Section 9 'Design drawings and specifications'. AISC 303-10, April 2010.

Standards Australia, AS 1100.101–1992, 'Technical drawings – General principles' including Amendment 1 of 1994.

Standards Australia, AS 1100.201–1992, 'Technical drawing – Mechanical engineering drawing' including Amendment 1 of 1994.

Standards Australia, AS 1100.301–1998, 'Technical drawing – Architectural drawing' including Amendment 1 of 2011.

Standards Australia/ Standards New Zealand, AS/NZS 1100.501–2002, 'Technical drawing – Structural engineering drawing'.

Australian Steel Institute, 'Australian steel detailers handbook', 1st edition, 1999 (reprinted 2001 and 2003).

Standards Australia, AS/NZS 1554.1-2011 'Structural steel welding Part 1 Welding of steel structures'

Steel Construction New Zealand, 'STEELDOC Code of practice for structural steelwork documentation', SCNZ-12:2006.

Australian Steel Institute, Design Guide 3 'Web side plate connections', Design Guide 4 'Flexible end plate connections', Design Guide 5 'Angle cleat connections', Design Guide 10 'Bolted moment end plate beam splice connections', Design Guide 11 'Welded beam to column moment connections', Design Guide 12 'Bolted end plate to column moment connections', Design Guide 13 'Splice connections'. Refer to latest editions of all Design Guides.

APPENDIX - RECOMMENDED DRAWING NOTES FOR STRUCTURAL STEEL

A.1 GENERAL NOTES

A.1.1 Construction using these structural drawings shall only commence if the structural steel drawings are designated “Issued for Construction”.

A.1.2 Dimensions shall be taken from architectural drawings only. Structural steel drawings shall not be scaled to obtain dimensions.

A1.3 The structural steel detailed on these drawings has been designed for the following loads:

Dead [provide details]

Superimposed [provide details]

Wind [provide details]

Earthquake [provide details]

A.1.4 The structural steel shown on these drawings has been designed in accordance with AS 4100-1998 including Amendment 1 of 2012, for members other than purlins and girts, and AS/NZS 4600 for purlins and girts.

A.1.5 No changes or substitutions may be made to any structural steel element documented in these structural steel drawings without reference to and approval by the structural engineer.

A.1.6 These structural steel drawings shall be read in conjunction with all architectural and other relevant drawings. Any discrepancies in the structural steel drawings shall be referred to the structural engineer for resolution.

A.2 NOTES ON FRAMING PLANS, SECTIONS AND ELEVATIONS

A.2.1 Fabrication and erection of the structural steel shall comply with Sections 14 and 15 respectively of AS 4100-1998 including Amendment 1 of 2012. Positions of base plates to all vertical elements to be accurately surveyed and provide survey certificates of all erected steelwork indicating conformance with tolerances specified in Sections 14 and 15 of AS 4100.

A.2.2 During erection, the structural steel shall be maintained in a stable condition and no part shall be overloaded. Temporary bracing not shown on the structural steel drawings shall be provided by the Builder as required.

A.2.3 Unless noted otherwise in the member schedule, all structural steel shall comply with the following Australian Standards in respect of grade and conditions of supply:

Rolled sections	AS/NZS 3679.1	Grade 300
Welded sections	AS/NZS 3679.2	Grade 300
Hollow sections	AS/NZS 1163	Grade C350
Purlins/Girts	AS 1397	Grade G450 Z350

Copies of test certificates complying in contents with and confirming full compliance with all the requirements of the above Standards for the relevant grade shall be supplied to the structural engineer.

A.2.4 All beams and rafters shall be supplied with any natural camber up. Additional camber shall be as noted on these structural steel drawings.

A.2.5 All members shall be supplied in single lengths by the distributor and splices shall only be permitted in the locations shown on these structural steel drawings. Requests to make up lengths using full penetration butt welds shall be submitted to the structural engineer for approval.

A.2.6 Structural steel members to be concrete encased shall be unpainted. Concrete encasement shall be to details provided by the structural engineer.

A.2.7 Structural steel to be galvanised shall conform to AS 4680 with a coating mass of 600 gm/sq metre (average), 550 gm/sq metre (minimum).

A.2.8 Structural steel to be painted shall have the following corrosion protection: [provide details].

A.2.9 Structural steel to be fire protected shall have the following finishes applied: [provide details].

A.2.10 An experienced shop detailer shall prepare separate shop detail drawings from the architectural and structural steel drawings. Fabrication shall not commence until the structural engineer and architect so advise.

NOTE: member schedule on the structural drawings should indicate member designation/member size/grade of steel/camber/any special issues involved.

A.3 NOTES ON STRUCTURAL STEEL DETAIL DRAWINGS

A.3.1 Bolting categories shown on these structural steel details shall be those defined in Clause 9.3.1 of AS 4100 (namely 4.6/S, 8.8/S, 8.8/TB, 8.8/TF). Test certificates confirming full compliance with the relevant Australian Standards (AS 1111 or AS/NZS 1252) and any other Australian Standards cited therein shall be supplied to the structural engineer.

A.3.2 Bolts shall be installed in accordance with Clause 15.2.3 of AS 4100 and bolts requiring tensioning (8.8/TB and 8.8/TF) shall be installed in accordance with Clauses 15.2.4 and 15.2.5 of AS 4100 using either the part-turn method or a direct-tension indication device. The torque control method shall not be used.

A.3.3 Unless noted otherwise, all bolts, nuts and washers shall be galvanised.

A.3.4 All bolt holes shall be 2mm larger than the nominal bolt diameter except where slotted or oversize holes are shown on the structural steel details. All holes shall comply with Clause 14.3.5 of AS 4100. Plate washers shall be provided where required by Clause 14.3.5.

A.3.6 All cut surfaces shall comply with Clause 14.3.3 of AS 4100.

A.3.7 All welding shall comply with AS/NZS 1554.1 unless noted otherwise on the structural steel details. Welding category shall be SP unless noted otherwise. All weld metal shall have a nominal weld metal tensile strength of 490 MPa unless noted otherwise.

A.3.8 The extent of non-destructive weld examination required shall be as follows: [provide details]. All non-destructive examination shall comply with the requirements of AS/NZS 1554.1 and shall be carried out in accordance with the Australian Standards cited in AS/NZS 1554.1.

A.3.9 All welding personnel shall be qualified in accordance with Clause 4.12 of AS/NZS 1554.1.

A.3.10 For base plates, provide a template with setting out lines clearly marked or cage anchor bolt group in order to ensure accurate positioning of anchor bolts to be cast in. Support steel attached to base plate with steel wedges /packers until grouted.

A.3.11 Connection cleats shown on the structural drawings where not identified specifically, shall be either Grade 250 plate to AS/NZS 3678 or Grade 300 flat bar to AS/NZS 3679.1.