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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.

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.

There is currently increasing use of this approach for projects in Australia. Significantly, with the vast improvements in technology, the implementation of 3D modelling and on-site 3D laser scanning, the ability for the steel detailer to accurately model in 3D the complete project has cemented their involvement as a valued member of the design team. In fact, the Steel Detailers Association has recently been renamed to the Australian Construction Modellers Association (Refer https://www.austcma.org.au/) reflecting the increasing importance of 3D in what is becoming a 'digital construction' supply chain.

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 RFIs 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

1. The reference number and date of the applicable design Standard;
2. The nominal loads;
3. The corrosion protection;
4. The fire resistance level;
5. 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) ...Details of the construction category or categories required;
(j) ...Details of the corrosion protection required;
(k) ..Any requirement for architecturally exposed structural steelwork;

(l) ...Any specific tolerances if different to those specified in AS/NZS 5131;
(m) .Any requirement for selection of materials to avoid lamellar tearing;
(n) ..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”.

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 9.6.3.10(A) 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.

AS/NZS 5131 Requirements

The publication of AS/NZS 5131 has acted to bring together all of the requirements for fabrication and erection of structural steel into one Standard. In respect of documentation it references the ‘construction specification’ as providing the required inputs for defining the technical requirements for fabrication and erection. The required information to be contained in the construction specification is defined in Clause 4.1.1. This information is essentially consistent with the requirements specified in AS 4100 noted above but includes also:

(a) Any additional information, options and assignment of responsibilities note in Appendix B
(b) Responsibilities for managing compliance

A feature of AS/NZS 5131 is the definition of the range of baseline requirements and, on top of this, the specification of additional mandatory and optional requirements that the engineer/specifier may define in the construction specification. This ensures the Standard and the NSSS can flexibly accommodate project-specific requirements. The presentation of the NSSS acts as an effective checklist for engineers and specifiers to ensure they consider all elements required.

AS/NZS 1554 Requirements

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, AS/NZS 5131 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.

REQUIREMENTS FOR THE SPECIFICATION

The 2020 revision to AS 4100 has defined the ‘construction specification’ as the “set of documents covering technical data and other requirements for a particular steel structure, including those specified to supplement and qualify the provisions of this Standard”. This is also consistent with the same requirement in AS/NZS 5131.

Clearly the construction specification is intended to be the complete set of documentation required to define the construction of the project, including design drawings, the engineer’s specification and associated documentation. The drawings and engineer’s specification sets the clear benchmark for the technical inputs to the project and must be well developed and comprehensive in order to ensure the project commences efficiently and has risk-minimised fit-for-purpose outcomes.

Recognising how comprehensive AS/NZS 5131 is, but also the shear extent of information provided, ASI has developed the ‘National Structural Steelwork Specification’ (NSSS) and corresponding ‘Standard Drawing Notes’ (SDN) to provide engineers a robust implementation of AS 4100 and AS/NZS 5131 in project process. The NSSS and SDN are free downloads in Word and PDF format from the ASI website. We encourage engineers and specifiers to adopt these documents as-is or in modified form. A standardised structure and content to the structural steelwork specification will provide efficiencies, cost savings and minimise project dislocation due to misunderstandings.

DUTY OF CARE

The Workplace Health and Safety (WHS) Regulation and ‘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”. Clearly, duty of care for designers, specifiers, fabricators, detailers and those that manage the construction of the project includes ensuring that adequate information is provided through the supply chain to ensure safe outcomes for the project, both during construction and in subsequent use. The Standards noted above define the extent of that ‘adequate information’.

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) Reduced durability and higher maintenance costs;
(7) Life safety risk due to incorrectly specified or installed materials and components;
(8) Time delays as matters in dispute are resolved via requests for information;
(9) Increased contractual disputes;
(10) 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 demonstrated by the ASI Standard Drawing Notes;
- 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 demonstrated by the ASI Standard Drawing Notes;
- 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 and also in the Standardised Structural Connections book. Alternatively, firms can produce their own set of standard details by creating a library of such details;
- The ASI Design Guides and Standardised Structural Connections book 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 may 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 Plan 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.

AS/NZS 5131 provides guidance on the use of building information modelling in Clause 4.3. It requires the following issues to be addressed:

(a) Production of a digital fabrication model consistent with the digital design model.

(b) Establishing the owner of the digital design model and ensuring the rights and obligations of ownership are clearly understood.

(c) Requirements and responsibilities for accuracy and maintenance of the digital design model.

(d) Preferably, utilisation of an open Standard for the exchange of digital steelwork data.

(e) Implementation of digital document management, version control and a system to record review, approval and final release of the digital fabrication model for preparation of shop detail documentation and fabrication of structural steel.

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