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MANAGING WELD QUALITY

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ABSTRACT

Due to the safety critical nature of structural steel components, international best practice dictates independent assessment of steel fabricator manufacturing control systems. The introduction of the Steel Fabricator Certification (SFC) scheme in September 2014 was an important milestone for NZ's structural steel fabrication industry. The Scheme ensures participating fabricators not only manufacture to the specified quality, but that they also have appropriate personnel and quality management systems in place that meet national and international best practice standards. Weld quality is at the centre of the SFC scheme, and the welding quality management standard AS/NZS ISO 3834 and underlying fabrication standards AS/NZS 1554 and NZS 3404.1:2009 are the key certification planks.

Welding is a "special process"

Welding is referred to in ISO 9000 as a "special process". Special processes in manufacturing are those processes for which the quality cannot be fully verified by final inspection and which require special competence controls before and during operations if quality is to be guaranteed. For products to be free from serious problems in production and in service, it is necessary to provide control from the design phase, through material selection, into manufacture and subsequent inspection. Quality cannot be inspected into a welded product, it has to be built into it.

With this in mind, in 1994 European standard EN 729 was developed to identify all the factors that could affect the quality of the welded product and need to be controlled at all stages, before and during welding. The objective was to specify quality requirements for fusion welding of metallic materials and to provide guidance on quality management systems for fabrication, manufacture, construction and maintenance.

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The international community has realised the benefits of the European initiative and the ISO 3834 series of standards, which are equivalent to EN 729, were subsequently published for the wider global markets. New Zealand and Australia adapted ISO 3834 to suit other codes and standards besides the ISO standards referenced in ISO 3834.

The New Zealand fabricators are familiar with this approach as the majority of the requirements of ISO 3834 have been gradually included in AS/NZS 1554 standard series.

People make it work – Welding Supervisors

A key feature of ISO 3834 is the requirement to ensure that people with welding responsibilities are competent to perform those responsibilities. ISO 3834 is supported by a host of other welding related standards such as: ISO 14731 Welding coordination – Tasks and responsibilities, which states that the tasks and responsibilities of personnel involved in welding-related activities (e. g. planning, executing, supervising and inspection) should be clearly defined. For all tasks assigned, welding coordinators shall be able to demonstrate adequate technical knowledge to ensure satisfactory performance of these tasks.

ISO 14731 requires that welding related tasks are documented with the responsible welding coordinator. Responsible welding coordination personnel shall be allocated from one of the following groups, depending on the Part of ISO 3834 applicable: personnel with comprehensive technical knowledge, personnel with specific technical knowledge and personnel with basic technical knowledge.

Section 4.12, AS/NZS 1554.1:2014 makes reference to ISO 14731 requiring welding coordination personnel (supervisor) to comply with the qualification requirements of the standard.

In-house welding inspection

A key requirement of the ISO 3834 system is inspection at appropriate points in the fabrication process in particular before, during, and after welding. The inspection must be performed by the fabricator (i.e. “in-house” or “first party” inspection) as a part of the production quality control. It is also referred to as “checks and tests” in AS/NZS 1554.

One of the key inspection factors is the implementation of an Inspection and Testing Plan (ITP). The ITP should be developed by the fabricator’s Responsible Welding Coordinator and welding supervisor. In-house welding inspection is usually supplemented by some degree of third party inspection as required by the Engineer. While the type and quantity of third-party inspection and NDT is defined by contract requirements and is typically less than 100%, in-house visual examination should cover all welding.

It is the intention of ISO 3834 that first-party visual inspection complies with the requirement of application Standard; for structural steel work AS/NZS 1554.1 and AS 3978. Those performing in-house checking/inspection must be competent. Section 7 AS/NZS 1554.1 states that a third party inspector should have at least the qualification required for a Welding Supervisor (e.g. AS 2214) and this requirement should also apply to first party (in-house) inspectors.

Including in-house inspection reports in the quality documentation supplied to a Client will assist in providing a high level of confidence in a fabricator’s quality management system.

The effectiveness of the welding management system depends to a large extent on the monitoring of performance, analysing records and introduction of measures to eliminate “waste” in the fabrication process. In-house welding inspection offers excellent resource for data mining and analysis for this purpose.

Third-party inspection

The respective roles of the AS/NZS 1554 welding supervisor and welding inspector in the performing of “inspection” are an on-going issue in our industry. As the term “inspection” is not well defined in the Standard it has come to have different meanings to different parties.

A typical definition for inspection in this context is: verifying conformity of the welding fabrication with the specific requirements of the Standard, contract and specification by measuring, examining, testing, gauging, checking, and verifying.

Welding inspection is defined as follows:

1. First-party Inspection – inspection of Contractor’s (in 1554 the “Fabricator’s”) work by the Contractor’ own inspection staff as explained above;
2. Second-party Inspection – inspection of the Contractor’s work by an inspection service employed by the Contractor;
3. Third-party Inspection -- inspection of the Contractor’s work by an independent inspection service employed by the Client or another third party.

Naturally option 3 offers a higher degree of independence of the inspection job.

To optimise the inspection effort, it is recommended to identify collapse critical members by applying the concept of weld failure consequence category and seismic demand category in accordance with the Section 8, NZS 3404.1:2009 where possible or practical. Specifying inspection requirements is the responsibility of the Engineer.

Welding Procedures

NZ structural steel welding standard AS/NZS 1554.1 Section 4.1.1 states - “The fabricator shall establish a welding procedure and list the applicable parameters in the welding procedure qualification record (also known as PQR or WPQR), which shall be held as a record and shall be available for examination.”

AS/NZS 1554 provides for “Pre-qualified” welding procedures that minimise the amount of testing required. The trade-off for less testing is that the essential variables applicable to prequalified weld joints are relatively limiting when compared to some other standards/codes.

While the pre-qualified approach is relatively strict on joint details the essential variables for welding current and arc voltage are more relaxed. Providing a welder with a procedure written to the full permitted limits of current and voltage may not achieve the required degree of quality control.

If there is any risk of a welder using unsuitable settings, the procedure should be more specific; for many types of work it is more reliable to specify narrower rather than wider settings.

Although the WPS is one of the key elements of the welding quality system, it can only work if the welder follows it. According to ISO 3834 and AS/NZS 1554 this is a responsibility of the Welding

Supervisor (or Welding Coordinator) to make sure that the welders are trained to understand and follow the relevant WPSs on every job.

Compliance with AS/NZS 1554.1 and NZS 3404.1

In order to achieve compliance with the Building Code, the fabricated item should comply with all normative requirements of the standards NZS 3404.1:1997, NZS 3404.1:2009 and AS/NZS 1554.

Fabricators certified to the requirements of the ISO 3834.2 as a part of the New Zealand Steel Fabricator Certification Scheme SFC are required to produce relevant documentation co confirm compliance with the above standard for every job performed.

It is a responsibility of the Engineer to make sure the fabricator comply with the above requirements. Building officials and structural engineers rely on statements of compliance from fabricators (producer statement PS3) to help establish compliance of the structural steelwork with the Building Code. SFC, in conjunction with appropriate project quality documentation supplied by the fabricator, provides greater confidence for accepting a fabricator's statement of compliance.

Compliance of the fabricated (overseas) steelwork

In some limited cases, building officials and structural engineers may face a task of verifying compliance of the steel work that is going to be fabricated overseas. It is the responsibility of the Engineer to make sure that the overseas fabricator complies with applicable NZ standards and rules.

The overseas fabricator should comply with the welding quality management to ISO 3834.2 for the scope of work under AS/NZS 1554 standard framework. The fabricator shall have procedures and records to ensure that all stages of fabrication comply with client's specification and requirements of NZS 3404.1 and AS/NZS 1554.1. Detailed requirements can be found in the technical framework of the Steel Fabricator Certification (SFC) scheme www.http://steelfabcert.co.nz

In order to achieve compliance it may be necessarily to provide a full third-party supervision and inspection to the overseas fabricator. The quantity of NDT and inspection may need to be significantly higher than that recommended in NZS 3404.1 to verify compliance.

An important aspect for the safety of welded connections is the acceptance level of external and internal weld imperfections defined in AS/NZS 1554.1. Therefore, welding procedures and welder qualification tests performed to overseas standards usually need to be re-qualified due to the difference in the acceptance levels for weld imperfections.

There are additional considerations if steel is supplied to a non-Australian/ New Zealand material supply standards. AS/NZS 1554 prequalified welding procedures are only for AS/NZS material supply standards. Additional mechanical testing is required to qualify procedures for other material supply standards and all steel containing increased level of boron. In this context it is also important to note that the applicable welding procedure specifications should be approved for the particular job by the Engineer.

With regards to assessing compliance of the already fabricated steelwork; it has been largely accepted that the quality of welding cannot be fully verified by final inspection. A process orientated quality management approach is required in order to produce consistent results for seismic applications. Therefore evaluation of compliance of fabricated steelwork poses some significant risks

if the fabrication has not been directly controlled by the Engineer through the entire fabrication process.

A checklist given in the Appendix can be used as a guide to assess compliance of the fabricated steelwork. The checklist provides normative references to the corresponding sections of the NZS, AS/NZS standards and defines documentation required to claim compliance. Depending on the outcome of the assessment, the fabricated steelwork may be subject to additional NDT and (destructive) testing.

ISO 3834 – A key element of the Steel Fabricator Certification Scheme

ISO 3834 is referenced in the New Zealand Steel Structures and Welding standards (AS/NZS 3404.1:2009 and AS/NZS 1554.1 respectively). ISO 3834 has also been adopted as AS/NZS ISO 3834.

The introduction of ISO 3834 as a key certification plank of the Steel Fabricator Certification (SFC) scheme reflects the structural significance of the quality of welded connections, particularly those subject to an elastic demand during major seismic events.

The SFC takes into account a risk-based approach introducing four Construction Categories (CC1-4) for steel structures covering a wide range of applications. While CC1 and CC2 apply for low risk structures such as low rise buildings, car parks, etc., CC3 and CC4 are specified for critical seismic applications, railway bridges, etc.

In order to perform work to the construction category CC3 and CC4, a fabricator has to be certified to ISO 3834 part 2 (comprehensive) for the technical scope of activities covered by NZS 3404.1 and AS/NZS 1554 standard series.

It helps to evaluate and pre-qualify steel fabricators and ensure they have the capability and quality management systems in place to undertake the types of work specified in the contract documents

Further info: http://steelfabcert.co.nz/

Benefits

Building officials rely on statements of compliance from fabricators (producer statement PS3) to help establish compliance of the structural steelwork with the Building Code. SFC, in conjunction with ISO 3834.2 certification, provides greater confidence for accepting a fabricator's statement of compliance.

The designer specifies a construction category, or categories, for the structural steelwork as a whole or for various components only. It is no need to produce a long list of requirements of the standards in project documentation.

For fabricators, the main benefit of implementing SFC & ISO 3834 approach will be cost saving due to less rework and more efficient technology. This is largely achieved by the implementation of Technical Review requirements that eliminates potential errors at the initial stage of the project and adequate control over welding operation. Becoming a certified fabricator demonstrates to your key clients your commitment to quality.

References

ISO 3834 (Part 1 to Part 6): Quality Requirements for Welding – Fusion Welding of metallic materials.

ISO 14731: Welding coordination — Tasks and responsibilities

AS/NZS 1554 standard series

NZS 3404.1 Steel Structures Standard

Steel Fabricator Certification: http://steelfabcert.co.nz/

Appendix: Checklist to assess compliance of fabricated steelwork

#	Item	Normative Reference	Documentation required to claim compliance
Materials			
1	Do all construction materials comply with standards specified and records available?	NZS 3404.1:1997, Section 2.2	Material test certificates
2	Are alternate material supplied to an internationally recognized standard?	NZS 3404.1:2009 clause 2.2.1	Material test certificates
3	Has a metallurgist or a materials engineer confirmed that the material supplied to an alternate internationally recognized standard is equivalent to a material standard referenced from NZS 3404? (NOTE)	NZS 3404.1:2009 clause 2.2.1	Record of approval by the design engineer
4	If an alternative material is approved as equivalent to one reference in NZS 3404 (clause 2.2.1), how do they demonstrate the tolerances and distribution of mechanical properties of the as supplied material meets the requirements of the material supply standard recognised in NZS 3404?	NZS 3404 (clause 2.2.1)	Record of approval by the design engineer
5	Has the material been supplied with test reports or test certificates prepared by a laboratory accredited by signatories to the International Laboratory Accreditation Cooperation (ILAC) Mutual Recognition Agreement (MRA) on behalf of the manufacturer?	NZS 3404.1:2009 clause 2.2.2	Test certificates
6	Are construction materials traceable through the entire fabrication and construction process?	NZS 3404.1:2009 clause 3.1.2	As-built fabrication drawings, traceability records
Fabrication			
7	Does the fabricator have procedures/records to ensure that the following operations complies with client's specification and/or requirements of NZS 3404.1:		
7a	Cutting	NZS 3404.1:2009, Section 3.2.2	Production Quality Plan
7b	Transition of thickness and width for seismic members	NZS 3404.1:2009, Section 3.2.4.2	Production Quality Plan
7c	Holing	NZS 3404.1:2009 section 3.2.5	Production Quality Plan
7d	Straightening, curving and cambering	NZS 3404.1:2009 section 3.2.1	Production Quality Plan

7e	Tolerances	NZS 3404.1:2009 section 3.3.3	Production Quality Plan
8	Have all stages of construction (including welding) been adequately reviewed by a person who is competent to undertake the review?	NZS 3404.1:1997, Section 1.6.3.1	Record of review by construction reviewer
9	Does the fabricator maintain procedures to ensure work is within fabrication tolerances? Does the fabricator maintain dimensional check lists and reports as identified in the Quality Plan?	NZS 3404.1:2009 section 3.3.3	Dimensional inspection checklist reports
Welding			
10	Has welding been specified in accordance with AS/NZS 1554 Part 1, 2 or 5 as applicable?	NZS 3404.1:1997, Section 14.3.4	Project documentation
11	Have matters for resolution been resolved/addressed prior to welding and evidence exist?	AS/NZS 1554.1: 2011, Appendix D, items (a) to (y)	Technical review check list(s)
12	Has fabricator qualified welding procedures prior to welding?	AS/NZS 1554.1: 2011, Section 4.1.1, NZS 3404:1997 Section 1.6.3.2	Approval records required or third-party inspection reports confirming this
13	Have welders been suitably qualified to carry out tasks according to welding procedures (e.g. AS/NZS 2980)	AS/NZS 1554.1: 2011, Section 4.12, NZS 3404:1997 Section 1.6.3.2	Welder/welding operator qualification certificates
14	Do all construction materials to be welded comply with the AS AS/NZS grades listed in the AS/NZS 1554, Section 2.1, Item (C) and evidence exist?	AS/NZS 1554.1, Section 2.1, Item (C)?	Material test certificates Record design engineer's approval
15	If the answer to the above is "not", has the weldability of alternative steel grade been established and evidence exist?	AS/NZS 1554.1, Table 6.6.1(B) AS/NZS 1554.1, Section 7 AS/NZS 1554.1, Section 5.3.4	PQR/WPS Qualification test reports
16	Have welding consumables been selected in accordance with the (seismic requirements of) standard?	NZS 3404.1, Section 2.6.4.5.2 AS/NZS 1554.1, Section 6	Welding consumables test certificates showing Ships Classification Societies Grade 3 approval (as applicable)
17	Have welding consumables been used within the welding parameter ranges specified by the manufacturer and the standard.	NZS 3404.1, Section 2.6.4.5.2, Item (b)	Welding inspection reports confirming the suitability of WPS or records of review (see below)
18	Have welding procedures been approved prior to welding by the design Engineer and evidence exist?	NZS 3404.1:1997, Section 1.6.3.2, Item (4)	Records or review and approval prior to welding.
19	Has welding been carried out under the supervision of a welding supervisor qualified in accordance of the Clause 4.12.1 of AS/NZS 1554.1?	NZS 3404.1:1997, Section 1.6.3.2, Item (2) AS/NZS 1554.1: 2011, Section 4.12.1	Welding coordination personnel qualification records
20	Is there evidence (e.g. inspection reports) that welding complied with all the appropriate requirements of AS/NZS 1554 such as workmanship, quality of welds and	AS/NZS 1554.1: 2011, Section 5 and 6	Signed inspection and quality plans

	dimensional tolerances?		
21	Is there evidence that fabricator complied with a quality management system such as ISO 3834? (NOTE 2)	AS/NZS 1554.1:2011, Section 1.7.1	Copy of ISO 3834 part 2 or 3 certificate issued by a Certifying Body, or fabricator's quality documentation reviewed by a third party welding engineer/inspector demonstrating compliance with ISO 3834
22	Does the fabricator ensure that the following items are addressed to contract specification and/or NZS 3404.1 and AS/NZS 1554: a) Welding consumables for earthquake resisting structures b) Weld access holes c) Welding of continuity stiffeners in earthquake resisting members	NZS 3404.1:2009, Section 3.2.3.2 NZS 3404.1:2009, Section 3.2.3.3 NZS 3404.1:2009, Section 3.2.3.4	Quality Plans
Welding Inspection			
23	Has the extent of non-destructive examination been nominated/approved by the design engineer?	NZS 3404:1997, Appendix D, Section D2	Project documentation
24	Has inspection been carried out in accordance with the AS/NZS 1554?	AS/NZS 1554.1: 2011, Section 7	Inspection reports
25	Has welding inspection personnel been properly qualified and evidence exist?	AS/NZS 1554.1, Section 7.2	Welding inspection personnel qualification records
26	Has non-destructive examination personnel been properly qualified and evidence exist?	AS/NZS 1554.1, Section 7.4	NDT personnel qualification records
27	Do final inspection reports exist stating that inspected welds comply with the permissible level of imperfections of SP or FP weld as applicable?	AS/NZS 1554.1, Section 6 AS/NZS 1554.5, Section 6	Final inspection report(s)

NOTE:

Welding is recognised in ISO 9001 as "special processes" as the quality of welded products cannot be fully verified by final inspection. Therefore, Section 1.7 of AS/NZS 1554.1:2011 requires the fabricator to demonstrate that all welding and related activities are conducted under a suitable quality management system. Such a system should comply with the requirements of AS/NZS ISO 3834