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How to reduce the risk of Structural Steelwork failing in your projects

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Abstract:

A trend towards the increased use of a Design & Construct procurement process has served to drive steel fabrication and construction costs down, but sometimes at the expense of inadvertently using non-compliant structural steelwork. This has resulted in maintenance problems and potential failure or a shortened life of the structure.

This is particularly relevant when the procurement process involves importing low-cost (and often non-compliant) steelwork from fabrication workshops in countries where regulatory and commercial practices do not necessarily align with the Australian community expectation for safety and risk.

A number of specific examples of non-compliances are covered including a case study of a failed steel truss alongside a roadway which will highlight the risk and consequences of non-compliant product. The initial cost saving between local and imported fabricated steel for the project was in the order of $100,000 whilst the additional cost to rectify and rebuild the truss was over 8 times the initial cost saving plus the legal fees and associated stress.

Responding to the need for stakeholders to be provided actionable tools to address non-compliance, the Australian Steel Institute (ASI) has developed the National Structural Steelwork Compliance Scheme (NSSCS) which includes a third party certification scheme for both Australian and overseas located steel fabricators. Details of the NSSCS are provided and how it can assist the whole supply chain to deliver improved safety outcomes for the Australian community. Reference is also made to a recent ASI Technical Note which provides an actionable framework to ascertain the compliance of structural steel.

Keywords: Steelwork, Compliance, Non-compliance, Fabrication, Certification

1. Introduction

The ASI is the nation's peak body representing the entire steel supply chain, from the primary producers through to end users in building and construction, resources, heavy engineering, and manufacturing.

A not-for-profit organisation, the ASI's activities extend to, and promote, advocacy and support, steel excellence, standards and compliance, training, events, and publications. The ASI provides marketing and technical leadership to promote Australian-made steel as the preferred material to the resources, construction, manufacturing, and public infrastructure industries, as well as policy advocacy to government.

One of the more recent focus areas for ASI has been steelwork compliance as part of a wider initiative by the building industry to address non-conforming building products. The compliance of building products is a demonstrable issue in the current procurement environment, with both increasing importation of products from countries whose regulatory and commercial practices do not align with the Australian community expectation for safety and risk, and commercial pressure on local manufacturers and suppliers leading to a reduction in quality in some instances.

There is currently recognition of and focus on addressing the problems by a range of Government and industry organisations. Whilst Government can provide the framework to support improved compliance outcomes, there is an expectation that industry needs to rise to the challenge and provide practical implementation to meet community expectations for risk and safety, as defined by the National Construction Code (NCC), our Standards framework and Workplace Health & Safety (WHS) Act and Regulations.

Within this context the whole supply chain beginning with the client needs to be responsible for improved compliance outcomes. The client needs to set the scene to ensure that those representatives providing design and build services including Architects, Engineers, Builders and Steel Fabricators are aware of their obligations. In particular Engineers, as the primary technical reference in the process of designing and constructing a building or infrastructure project, have increased responsibility and pressure placed on them to provide professional guidance, balancing cost effectiveness against quality and the associated risk and safety obligations. Unfortunately, assessing the compliance of building products is not trivial, and few engineers have the time (within commercial constraints) to do it properly. Industry therefore needs to provide pragmatic, practical and cost effective tools to aid in this process.

This paper examines some of the current problems, and tools available to manage product compliance and discusses the National Structural Steelwork Compliance Scheme (NSSCS) which includes steel fabricator certification as a practical step towards providing the Australian community with improved safety outcomes for structural steelwork.

2. Problems to be addressed and AS/NZS 5131

The procurement, fabrication, and erection of structural steelwork for buildings, infrastructure and resources projects involves a supply chain that is as varied as it is long. Contractual relationships and commercial and political pressures all influence the ultimate procurement scenario, which can also change markedly over the period of project delivery. The Regulatory environment is also continually recalibrating, influenced by tensions that exist between our obligations under World Trade Organisation (WTO) requirements for free trade, performance solutions enabling innovation and the most fundamental requirements to ensure our community can expect risk-minimised safe solutions for their workplaces and habitation. Images of some of the problems experienced with structural steelwork are shown in Figure 1.

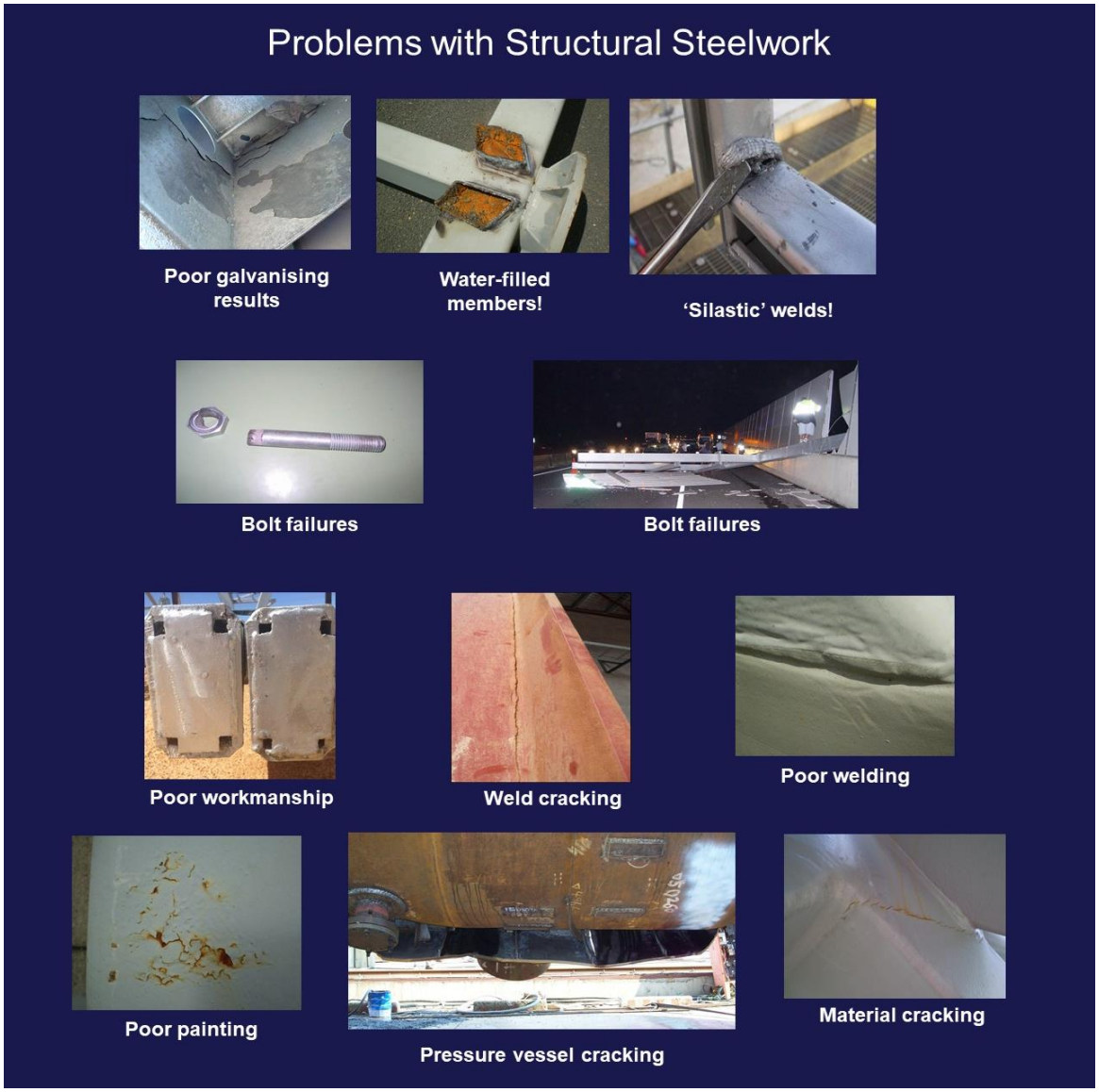

Figure 1: Problems with Structural Steelwork

Case Study

This case study has been chosen from a group of case studies prepared by ASI as it best highlights a number of serious non-conformances.

Non-compliant imported steel fabrication for a steel truss supporting a glass sound barrier

Project: A glass acoustic noise barrier alongside a Sydney roadway, comprising a 62m span triangular tubular truss fabricated from up to 250 mm square steel hollow sections.

Details of the failure: This project was put out to tender, and the winning tender (lowest price) was based on imported fabricated steelwork from Vietnam. The resulting imported fabricated steelwork illustrated significant defects with the truss defecting on installation.

Issues determined:

- Steel was well below the specified yield strength. Independently measured by a NATA certified laboratory at 338 MPa versus the 450 MPa specified.
- Lower capacity fillet welds used instead of the specified full penetration butt welds
- The welded joints indicated weld cracking. Chord members displayed cracking in the steel.
- The workmanship of the tube and fabricated structure was non-compliant to Australian Standards.
- Many of the tubular members were below the design wall thickness i.e., lower capacity sections were utilised.
- The cross chords were filled with water, presumably to increase component weight to that specified for shipping purposes (suspected fraud).
- The protective coating was non-compliant. It was independently verified by a NACE certified coating inspector that the top urethane coat was missing, and signs of rusting were evident.

Figures 2 to 5 show images of the truss and some of the noted problems.

The builder undertook significant repairs onsite, including reinforcing the areas where cracking occurred in the junction between cross beams and main truss beams and welding reinforcing tubing alongside sections of the cross beams that had split. The truss still failed in service and the fabricator responsible for importation of the truss structure went into insolvency

The project was rebuilt by an Australian fabricator to largely the same design but with compliant materials and workmanship.

The initial cost difference between local and imported fabricated steel was approximately $100,000. The rectification and rebuild costs were approximately $810,000.

Unfortunately, the ultimate responsibility was passed onto the engineer by the builder and the overall cost including legal fees was borne by the engineer's Professional Indemnity Insurance.

Figure 2: The non-compliant steel truss

Figure 3: Fillet welded connection instead of butt weld

Figure 4: Poor paint finish

Figure 5: Under-cut (concave) weld below required thickness

AS/NZS 5131 Structural Steelwork – Fabrication and Erection

The publication of AS/NZS 5131 'Structural steel – Fabrication and erection' (Ref.1) has introduced a risk-based approach to fabrication and erection of structural steel, for both permanent structures and also temporary works.

The foundation of AS/NZS 5131 is essentially a statement of 'good practice', defined by a combination of existing Australian fabrication practice and input from international practice. The processes for material procurement, cutting, holing, shaping, assembly, welding, bolting, surface treatment and erection that form the foundation for good practice are consistent with our existing Standards suite.

Project risk, including the consequences of failure and the complexity of the construction works, is recognised through categorisation into one of four 'construction categories' (CCs), as shown in Figures 6 & 7. Construction Categories of CC1 to CC4 in order of increasing risk profile are defined. The CC affects predominantly the level of documentation and traceability required to establish veracity of the input products and completed fabricated components and certain critical aspects of functional processes such as cutting, holing, welding, and high strength bolting. The assessment of the construction category is provided in AS 4100 (Ref. 2) and AS/NZS 5131 (Ref. 1) and discussed in ASI Technical Note TN011 (Ref. 3).

IMPORTANCE LEVEL		1		2		3		4	
SERVICE CATEGORY		SC1	SC2	SC1	SC2	SC1	SC2	SC1	SC2
FABRICATION CATEGORY	FC1	CC1	CC3	CC2	CC3	CC2/ CC3 (1)	CC3	CC3	CC3
	FC2	CC2	CC3	CC2	CC3	CC3	CC3	CC3	CC4

Note 1: The assessment of CC2 or CC3 for this designation marked should be based on engineering judgement and the relative simplicity of fabrication and erection of the structure.

Figure 6: AS/NZS 5131 risk matrix assessment of the Construction Category (CC)

Construction Category	Example structure types (1)
CC1	• Farm sheds; greenhouses; fences; gates; small signs
CC2	• Low- to medium-rise buildings (industrial buildings, residential buildings, offices, residential apartments and retail) • Single and two level school buildings and structures
CC3	• Large structures (e.g. high-rise buildings) • Large stadia • Road and rail bridges • Post-disaster buildings (e.g. hospitals)
CC4	• Structures with extreme consequences of structural failure

Notes:

The structure types shown are indicative only. The assessment of the construction category is the responsibility of the engineer based on the guidance provided in AS 4100 and AS/NZS 5131. The 'Building importance level' from the NCC is one factor in the assessment of the construction category.

Figure 7: AS/NZS 5131 Construction Categories (CC) and example structure types

De-specification and product substitution

The number of engineers specifying AS/NZS 5131 Structural Steelwork – Fabrication and erection in their design documentation is increasing. However, there is a lack of compliance with the standard on many projects. One justification mentioned for this lack of compliance is that AS/NZS 5131 (Ref. 1) is not yet referenced in the current edition of the National Construction Code (NCC) (Ref. 4) so is not yet "law". It is important to note that AS 4100 makes reference to AS/NZS 5131, so any project that uses AS 4100 for design must also utilise AS/NZS 5131. If a Construction Category is not specified in the engineering documents, then it will automatically be assumed to be CC2.

The latest version of AS 4100 will be called up in the 2022 edition of the NCC and as the latest version of AS 4100 makes reference to AS/NZS 5131, both of these standards are then "law".

Another reason for the lack of compliance is due to the original design engineers not being involved with projects once the design drawings leave their offices.

In some instances, once a builder wins a project with a low tender price, they then engage another engineer to re-engineer the structure in order to reduce construction costs. This process can involve what is termed de-specifying where a specified CC3 level may be reduced to a CC2 level in order to use a lower cost fabricator without the required systems in place; the reference to AS/NZS 5131 (Ref. 1) is totally removed from the specification, and in some cases the project is re-designed to suit overseas fabrication (product substitution) e.g., including adding connections to reduce the length of steel sections to suit shipping containers.

Concerns regarding spot testing of imported fabricated steelwork

There have been cases where an importer has provided a local engineer with a single or small batch of test results of imported steelwork. These tests have shown a yield strength value equal to or above that of the specified Australian manufactured steel, so the engineer has approved the use of the imported steel. Unfortunately, by basing approval on a single or small number of test results the certifying engineer is taking on considerable risk as the substituted steelwork is not likely to meet Australian standards.

It is important to understand that a single batch test of steel only affords a snap-shot of the manufacturer's production at a point in time. A batch test does not give any indication of long-term quality levels. A statistical approach utilising test data collected over a period of time is required to determine this.

The limit state design basis for the Australian steel design Standard AS 4100 (Ref. 2) is predicated on and calibrated against five percentile characteristic material properties, as required under the National Construction Code (NCC) (Ref. 4). Australian steel product standards define characteristic strength based on the five percentile (95% passing), which is assessed from long term quality testing data

A single test result provided on a manufacturer's test certificate, or a single testing outcome, cannot be used to establish the five percentile characteristic strength.

Figure 8 indicates a typical distribution of actual yield stress from an Australian steel manufacturer testing for a 300 Grade steel. Note that the majority of tests are significantly higher than 300 MPa, with an average of around 350-355 MPa.

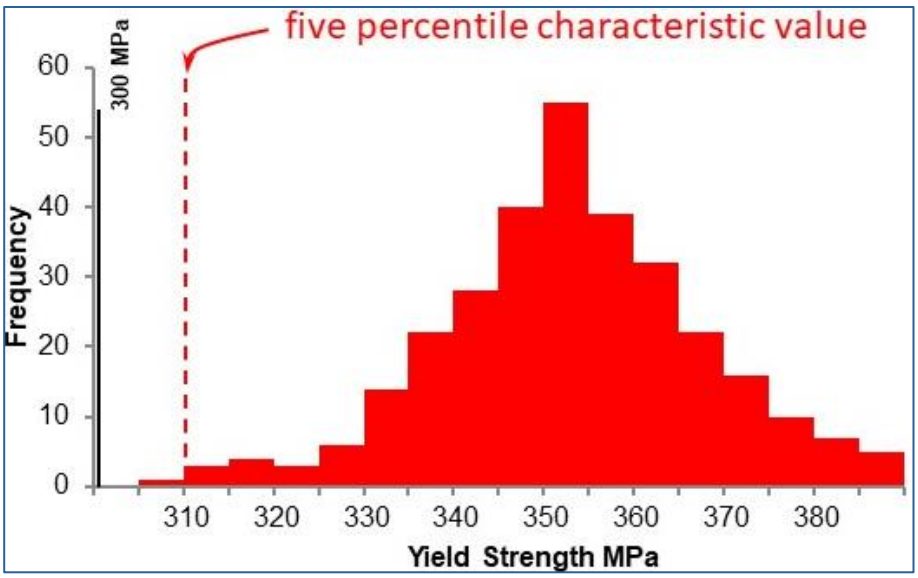

Figure 8: Yield strength histogram based on manufacturer production testing – 300 Grade steel

It is important to understand that test data on test certificates taken from a single batch of steel cannot be used directly as the basis for design or for (re)grading of the product, as this data does not represent the five percentile (95% passing) material properties to which AS 4100 design basis has been calibrated and the NCC requires. The Commentary to AS 4100 (Ref. 5) and ASI Tech Note 015 (TN015) (Ref. 6) provide further details. TN015 also provides a methodology to assess the five percentile characteristic value based on a statistically relevant minimum of at least three tests.

Specific issues with imported Welded 3 Plate Beams

Part of the de-specification process can involve the substitution of imported 3 plate welded beams for the specified hot rolled beams.

The 3 plate beams shown in Figures 9 & 10 are welded items which are fabricated overseas and made up of a web welded to a top flange and a bottom flange to make an "I" shape. These beams are structural members which comprise the "skeleton" of a structure, so are considered a high safety risk.

The overseas fabricated 3 plate beams are considered to be bespoke items, so they need to comply with both AS 4100 (Ref. 2) and AS/NZS 5131 (Ref. 1).

Some of the compliance issues identified regarding the imported 3 plate beams are:

- top and bottom flanges out of alignment.
- top and bottom flanges of different widths.
- pitted steel visible in flanges.
- inadequate welding of beams to end plates.
- suspected fillet welds used where full penetration butt welds are specified/required.
- unnecessary welded joints in the length of beams which increases the risk of failure due to a larger amount of potentially faulty welding.
- lack of documentation/information on welders' qualifications and competence.
- incorrect/inadequate material test certificates provided for the steel plates leading to a lack of knowledge of the chemical composition and strength of the steel plates.
- no material test certificates provided for some of the steel plates causing a lack of traceability of the steel.
- the overseas fabricator only providing test results for a sample of the steel used rather than the full batch testing results including statistical test data in line with what is required by Australian Standard AS 4100 (Ref. 2).

Figure 9: Imported welded 3 plate beams being unloaded from a shipping container

Figure 10: Imported welded 3 plate beams – extra joins increase risk of non-compliance

3. The National Structural Steelwork Compliance Scheme

Regardless of how well or clearly AS/NZS5131 (Ref. 1) defines product conformity, the assessment of whether a completed structure meets the requirements of the Standard is not a trivial task, in particular given the aforementioned procurement environment in Australia. There is increasing realisation that practical solutions are necessary in order to support robust compliance outcomes and that third party compliance schemes are desirable for safety critical items such as structural steel as noted in the Australasian Procurement and Construction Council (APCC) Procurement of Construction Products – A guide to achieving compliance (Ref. 7).

The National Structural Steelwork Compliance Scheme (NSSCS) has been developed by ASI to provide procurers with a straightforward cost-effective solution to improved compliance outcomes for fabricated structural steelwork.

The NSSCS comprises four components, as shown in Figure 11:

- Fabrication Standard: AS/NZS 5131 (Ref. 1), a risk-based fit-for-purpose approach as described elsewhere in this paper.
- Conformity Assessment: the framework defining how conformity to AS/NZS 5131 (Ref. 1) is assessed.
- Risk identification: assessment of the 'Construction Category' by the engineer.
- 3rd Party Certification: certification and auditing of fabricators by Steelwork Compliance Australia (SCA).

AS/NZS 5131 (Ref. 1), conformity assessment and risk identification by engineers have been discussed in other parts of this paper.

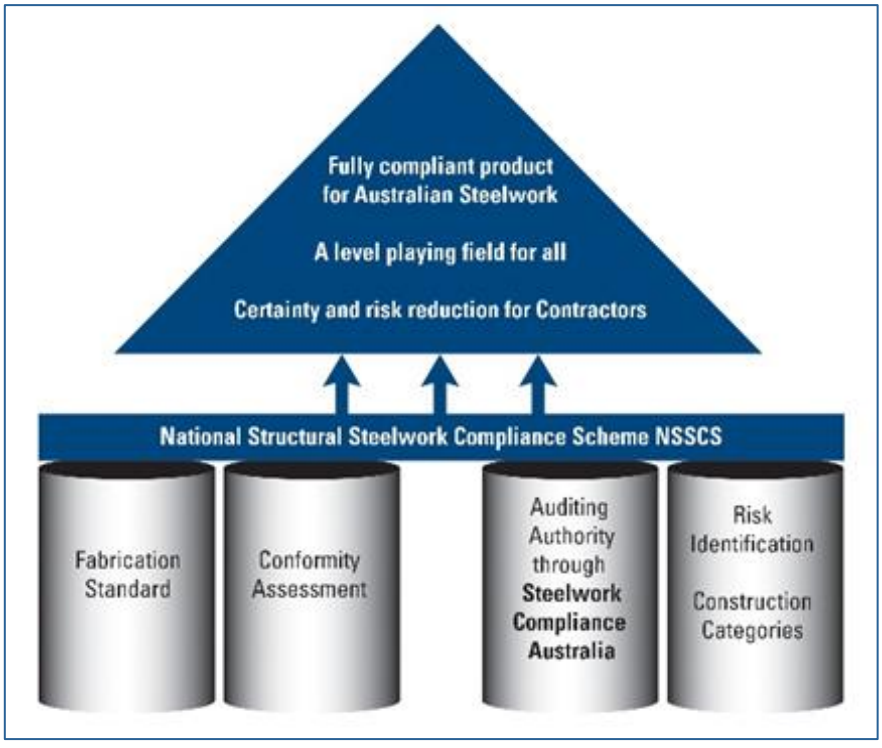

Figure 11: NSSCS overall structure

The objective of Steelwork Compliance Australia (SCA) is to provide independent certification of fabricators for the supply, fabrication, and erection of structural steelwork to be used in Australia, irrespective of the origin of the steel or fabricated steelwork product. This gives clients the ability to select fabricators who have been independently assessed as having capability to achieve compliance to the requirements of AS/NZS 5131 (Ref. 1) for the nominated Construction Category. SCA supports the pragmatic implementation of the NSSCS.

The process for certification comprises an initial assessment of the fabricator, a stage 1 desk top audit (which provides the fabricator feedback on how they are situated in respect to their compliance capability) before engaging on the Stage 2 site audit of the fabrication workshop. The scheme is funded by the steel fabricators being certified.

SCA has currently certified over 100 steel fabrication companies with many more in the process of becoming certified. The steel community in Australia, and in particular procurers, specifiers and builders wishing to ascertain the certification status of available fabricators, can access the website at http://www.scacompliance.com.au/ and freely review the list of certified fabricators. The South Australian (SA) government introduced compulsory fabricator certification 5 years ago on SA government projects. The SA process is managed by the South Australian Industry Advocate - website: https://industryadvocate.sa.gov.au/policy-and-resources/

4. The Responsibility of the whole supply chain to address problems with steelwork

In November 2012, the ASI held the seminar 'Implications of the new Work Health and Safety Act 2011 on Compliance in Construction Steelwork' in Brisbane with the support of Workplace Health and Safety Qld (WHSQ). ASI put questions to senior representatives from WHSQ on the relevance of product compliance to Designers', Contractors', and Importers' duties under the WHS Act.

These questions related to the responsibility of the various parties in the building chain to maintain standards within the environment of increasing global procurement of structural steel in Australian building projects. The increased demands, responsibility and risk placed on each member of the supply chain was discussed.

The full answers to the questions can be viewed on the ASI website at https://www.steel.org.au/ASI/media/Australian-Steel-Institute/PDFs/WHSQ-answers-to-questions-ASI-Brisbane-seminar-26-Nov-2012.pdf, but the overall message from WHSQ was that everyone in the building product chain has a shared responsibility for product compliance and safe structures, not only the engineer or building certifier.

In 2017, the Queensland government confirmed this view by introducing the first Australian chain of responsibility (CoR) legislation to address non-conforming building products. This legislation entitled "Building and Construction Legislation (Non-conforming Building Products—Chain of Responsibility and Other Matters) Amendment Act 2017" insists that all members of the building product supply chain, from the manufacturers, importers and wholesalers to the suppliers and installers, take responsibility for ensuring building products are compliant and fit for their intended purpose. Compliance with the legislation is managed by the Queensland Building and Construction Commission (QBCC).

Current Government Initiatives/Safeguards

The following 2 initiatives in place in Queensland do assist to address Non-conforming Building Products (NCBPs):

- Engineers Registration managed by the Board of Professional Engineers of Queensland.
- NCBP Chain of Responsibility legislation managed by the Queensland Building & Construction Commission (QBCC).

But the weakness of both of these initiatives is they don't necessarily prevent NCBPs from occurring. They rely on a complaint being lodged after an NCBP is identified and then potentially expensive rectification. And that is only of the NCBP's identified. What of those that slip through?

Engineers Registration

Stakeholders, in particular engineers, are generally not technically equipped to address compliance of fabricated structural steelwork. Properly ascertaining compliance is complex and highly technical. The average engineer is not trained to do this and should not be expected to have to be trained to do this. They should be able to rely on the product being compliant and need only check it is appropriate for the design. Putting in place compliance (Steel Fabricator Certification) as part of the process of creating the structure is much more robust and efficient than trying to train engineers to audit properly after the fact. Registering engineers does not fix this, because they do not know what they do not know regardless of being registered or not. Registration makes engineers more accountable, but without the hope of technically being able to do the proper job of ensuring compliance.

NCBP Chain of Responsibility

'Chain of responsibility' is a great concept, but it does rely on stakeholders understanding and recognising what is non-compliant. For engineers, ascertaining compliance is technically challenging, particularly with fabrication which utilises specialist processes like welding and ascertaining compliance of materials. SCA Fabricator Certification works in conjunction with the Chain of Responsibility (CoR) legislation, not instead of it. Every link needs to be connected to maintain traceability, which is what CoR does, but within each link we need to ensure the link itself is not broken.

5. How third-party certification of fabricators supports current safeguards to address NCBPs.

The Shergold/Weir Report "Building Confidence – Improving the effectiveness of compliance and enforcement systems for the building and construction industry across Australia"(Ref. 8) has identified independent third - party certification of products and services as a way to address NCBPs. Typically, compliance cannot be corrected after the fact without expensive, time consuming processes that are very dislocating for the project. The resulting project cost increases and poor results are less than ideal. In some cases, the structure needs to be re-fabricated. Third-party fabricator certification is insurance that the project has a better chance of compliance and meets duty of care obligations under Workplace Health & Safety (WHS).

A recognised transparent and quantifiable quality bar (Fabricator Certification) will help prevent stakeholders avoiding their duty of care by using a fabricator who cuts corners to produce non-conforming fabricated structural steelwork. Having a quantifiable bar such as Fabricator Certification makes it a lot easier to implement the very important step of policing. The lack of effective policing has been a feature of many state based regulatory regimes. The regulation may be first class, but the problem is that it is not policed and therefore can be abused. A properly implemented certification scheme has inbuilt review processes and the 'big stick' of de-certification of the Steel Fabricator. This layer of 'private policing' can make it easier for Government to augment its own policing regimes based on feedback from industry.

Auditing and certification of steel fabricators ensures that the steel fabricators have systems in place and the capability to produce fabricated structural steelwork to the compliance requirements of the appropriate Australian Standards for the relevant construction categories as defined in AS/NZS 5131 (Ref. 1). An additional benefit is that at all times there is a very easy and verifiable method for checking certification credentials by accessing the website of the certification authority.

The process to achieve the quality benchmark for Government is:

- Configure government procurement specifications to correctly reference AS/NZS 5131 (Ref. 1). The National Structural Steelwork Specification (NSSS) (Ref. 9) and Standard Drawing Notes (SDN) (Ref. 10) will help in this regard. Ensure the appropriate Construction Category is included in the specification.
- Nominate third party certification of steelwork under the NSSCS.
- Implement surveillance to ensure the intent of the procurement specifications has been actioned.

The benefits for clients and Government include:

- Assurance that the steelwork contractor is competent as assessed by an expert process.
- Assurance that the tender offer is based on a like-for-like quality comparison and not compromised on quality, therefore minimising likely costly rework and remediation.
- Management of risk and your duty of care under the Safe Work Australia 'Model Code of Practice - Safe design of structures' (Ref 11).
- Utilising a steelwork fabricator who has invested in training, apprenticeships, systems, and capability over those who quote on price alone.

6. Conclusion

ASI has developed the National Structural Steelwork Compliance Scheme (NSSCS) as an easily actionable tool to help ensure stakeholders and our community have compliant risk-minimised structures. ASI strongly recommends third-party certification of steelwork and is seeking to have the following wording included in specifications for all government building projects: "Compulsory auditing and certification of all Steel Fabricators by Steelwork Compliance Australia (SCA) to meet the requirements of AS/NZS 5131 prior to tendering on government projects."

The South Australian Government has successfully mandated this level of certification for projects funded by the South Australian Government since 2017. Hence the credibility and experience of SCA certification has been proven in the South Australian market.

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