Guide to the Use of International Standard Steels with NZS 3404 (Steel Structures Standard)

Part 1: Structural Hollow Sections – EN 10219

Report: SCNZ 114:2020

and

HERA R4-154

Authors:
Alistair Fussell, Kevin Cowie
Steel Construction New Zealand Inc.

Michail Karpenko
Heavy Engineering Research Assoc.

Published by:

Steel Construction New Zealand Inc.
17-19 Gladding Place
PO Box 76403
Manukau City
Manukau 2241
New Zealand
Phone: +64 9 263 5635
Fax: +64 9 262 2856

November 2020
ISBN 978-0-473-51663-5

Steel Construction New Zealand Inc. (SCNZ) is a member-based, not-for-profit society incorporated under the Incorporated Societies Act 1908.

SCNZ has three basic objectives, to:

- Promote awareness of the advantages of steel construction
- Foster excellence in the delivery of steel construction solutions
- Encourage training and career development within the steel construction sector

Document Control

Revision History			
Revision	**Date**	**Description**	**Prepared by**
4	21/04/2020	Co-author review document	AJF
5	6/05/2020	Amended document following KC review	AJF
6	8/05/2020	Michail Karpenko review document	AJF
7	12/06/2020	Amended document following Michail Karpenko review	AJF
8	30/06/2020	Stakeholder draft	AJF
9	14/09/2020	Final co-author review document	AJF

Table of Contents

1.0 Introduction

1.1 Background

Structural steels used in New Zealand building and infrastructure projects are typically manufactured to AS/NZS steel standards AS/NZS 1163 (SA/SNZ, 2016a), AS/NZS 3679.1-2 (SA/SNZ, 2016b, 2016d) and AS/NZS 3678 (SA/SNZ, 2016c). Due to the small size of the local market and manufacturer minimum order quantities, it can be challenging, and in some cases impossible, to source a limited range of AS/NZS steel products including medium-to-large-sized hollow sections, and larger plate sizes and thicknesses. The New Zealand Steel Structures Standard (SNZ, 1997a) has recognised steels manufactured to EN and JIS standards in addition to AS/NZS standards to address this challenge.

1.2 Purpose

The *Guide to the Use of International Standard Steels with NZS 3404 – Part 1: Structural Hollow Sections – EN 10219* is intended to promote and facilitate the use of a wider range of hollow sections for building and infrastructure projects.

1.3 Scope of Guide

The scope of the publication includes the design and welding of steel components utilising sections manufactured to EN 10219 in conjunction with the relevant steel structures (NZS 3404; SNZ 1997a), fabrication (AS/NZS 5131; SA/SNZ, 2016e) and welding standards (AS/NZS 1554.1; SA/SNZ, 2014). The material selection provisions of NZS 3404 are not applicable to hollow sections manufactured to EN 10219. In this Guide a material selection methodology appropriate for such steels is presented. As this methodology is outside the scope of NZS 3404, it represents an alternative solution to demonstrate Building Code compliance.

Recommendations are included for preferred section sizes and grades to increase supply options. In addition, exemplar specification clauses are provided to address differences in requirements between EN 10219 (CEN, 2006) and New Zealand steel sourcing practice.

1.4 Who Should Use this Guide?

This Guide has been prepared to assist all stakeholders engaged in the design (engineers), construction (builders, structural steel contractors and structural steel distributors) and consenting (building consent officials) of structural steel buildings and infrastructure projects.

1.5 Abbreviations

AS	Standards Australia
FPC	Factory Production Control
ITT	Initial type testing
MOQ	Minimum order quantity
NZS	New Zealand Standard
EN	European Standard
JIS	Japanese Industrial Standards

1.6 Definitions

Non-specific Inspection

Inspection carried out by the manufacturer in accordance with their own procedures to assess whether or not products defined by the same specification and manufactured by the same process are compliant with the requirements of the order.

The product inspected is not necessarily the product supplied (CEN, 2004).

Specific Inspection

Inspection carried out before delivery according to the product specification on the products to be supplied, or on test units of which the products supplied are part of, in order to verify that these products are in compliance with the requirements of the order (CEN, 2004).

Structural Steel Constructor

The party that manages the whole structural steelwork process from shop drawing to manufacture and completion of the erected structure (Fussell et al., 2018).

$\mathbf{f_y}$ - yield stress in MPa

$\mathbf{f_u}$ - tensile strength in MPa

Structural Steel

Steel material of various shapes and grades used in construction applications. This is the raw material from which fabricated structural steelwork is manufactured. With the exception of some plate, structural steel is produced overseas and imported as a 'raw' product to be fabricated in New Zealand (Fussell et al., 2018).

Structural Steel Distributor

Importers of structural steel for use in the construction industry. These companies have extensive facilities to warehouse large inventory and provide limited pre-processing of structural steels prior to fabrication.

Factory Production Control

Operational techniques and all necessary measures to regulate the conformity of the product to the requirements of the relevant standard (SA/SNZ, 2016b).

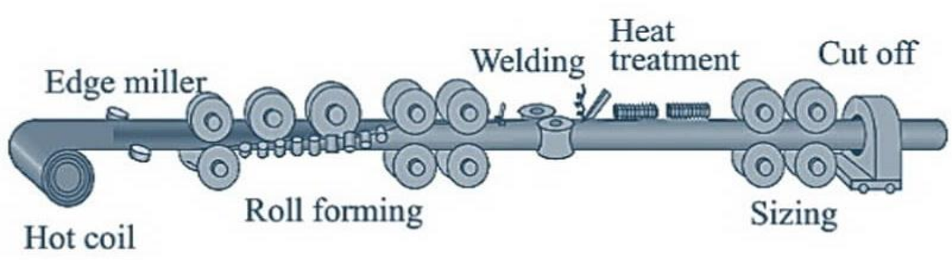
Steel Fabrication Certification (SFC)

The certification scheme to certify compliance of New Zealand steel fabricators with the Construction Category requirements of AS/NZS 5131.

1.7 Structural Hollow Section Manufacturing

Hollow sections are manufactured using either hot-forming (seamless) or cold-forming (longitudinal or spiral welded) processes. Seamless sections are outside the scope of this Guide. Cold-formed sections are produced from flat steel strip or coil. During the manufacturing process, the flat feedstock material is gradually formed into a round shape and the strip edges are welded using either electric resistance or submerged arc welding processes. Rectangular or square hollow sections require an additional step to pipe. The round pipe formed in the first step is subject to an additional shaping process to transform the circular section into the required square or rectangular shape. The forming process for producing cold-formed hollow sections with longitudinal welds is illustrated in Figure 1.

Figure 1
Cold-formed hollow section manufacturing process – longitudinal weld



Note.. Source unknown.

2.0 NZS 3404 Material Requirements

In this section, an overview of the NZS 3404 material provisions is given, including permitted steel grades and material selection.

2.1 Permitted Steel Grades

The Steel Structures Standard NZS 3404 permits the use of three types of steels:

Prequalified Steels

These structural steels are manufactured to a prescribed selection of AS/NZS, EN and JIS material standards. Such steels may be used without any further assessment or approval process to justify their use with NZS 3404.

Alternative Steels (non-Prequalified Steels)

These structural steels are manufactured to an international steel supply standard that is approved by an appropriate expert as compatible for use with the steel structures and welding standards (NZS 3404 and AS/NZS 1554.1). This approval process is outside the scope of NZS 3404 for establishing compliance with the New Zealand Building Code. No guidance is given in NZS 3404 as to the matters needing to be considered in the approval process.

Unidentified Steels

These are steels for which the grade is no longer identifiable. Such steels may be used, subject to the following requirements:

- Establish design parameters f_y, f_u based on test data using an appropriate statistical method, or
- Assume conservative design parameters for f_y and f_u, 170 MPa and 300 MPa respectively, and limit their use to elastic applications.

2.2 Material Selection

Under certain circumstances, structural steels may behave in a brittle manner (SNZ, 1997b). The NZS 3404 material selection provisions for seismic and non-seismic applications are intended to suppress brittle fracture and ensure steels for structural applications possess adequate ductility. These provisions are summarised as follows:

2.2.1 Non-seismic Applications

The material selection provisions in NZS 3404 have been adapted from AS 4100 (SA, 1998). The NZS 3404 provisions, however, include a wider range of steel grades, including seismic S0 steel grades and steels manufactured to EN and JIS standards.

Two methods may be used to select the required steel grade for non-seismic applications – the notch ductile method and the fracture mechanics assessment method. The former method is discussed in the following section. The latter approach, which is not commonly used, is discussed in more detail in NZS 3404.2 (SNZ, 1997b).

2.2.2 Notch Ductile Method

Steel grades are selected to operate in the notch ductile temperature range where the steel is insensitive to all but gross notches, weld defects or structural discontinuities (SNZ, 1997b).

An important point to note is that the selection provisions are based on notch ductile data (Charpy impact and crack tip opening displacement) for structural steels manufactured in Australia. In AS 4100, a note warns that the notch ductile provisions may not be applicable to steels of non-Australian origin as the tests have been performed on steels manufactured in Australia in the 1960s and ’70s. This note has not been reproduced in NZS 3404.

The key elements of the notch ductile method in NZS 3404 are:

1. Different steel grades are grouped into steel types based on mechanical properties (see Table 2.6.4.4).
2. The basic design temperature is the lowest one day mean ambient temperature (LODMAT). This is intended to represent the estimated lowest metal temperature encountered in service or during erection. LODMAT isotherms for New Zealand are given in Figure 2.6.3.1.
3. The design service temperature is taken either as the basic design temperature or the basic design subject to modification (if required).
4. Permissible service temperatures are presented in Table 2.6.4.1 based on steel type and material thickness.
5. The permissible service temperature from Table 2.6.4.1 must be modified if the material is pre-strained by fabrication processes such as cold bending.
6. Acceptable steel types are those with a permissible service temperature lower than the design service temperature.

A recent paper (Hobbacher & Karpenko, 2020) notes several limitations to the NZS 3404 material selection to suppress brittle fracture provisions. These include:

1. Limited applicability for steels of non-Australian origin
2. No accounting for:
    a. strain rate e.g. seismic vs non-seismic load rate
    b. residual stresses, including cold forming hollow sections
    c. section utilisation ratio (demand/capacity)
    d. welds
    e. cold forming
    f. imperfections, such as undetectable cracks.

2.2.3 Steels for Seismic Application

The material property requirements for seismic-resisting systems are presented in Table 12.4, NZS 3404. This table has been reproduced in Table 1 below.

Table 1

NZS 3404 Material for seismic application requirements

Item		Category 1, 2 and 3 members	Category 4
1	Maximum specified grade reference yield stress[1]	360 MPa	450
2	Minimum % total actual elongation[2]	25	15
3	Maximum actual yield ratio (f_y/f_u)[2]	0.8	0.9
4	Maximum actual yield stress[2]	≤1.33fy[4]	-
5	Minimum Charpy V-notch impact energy[3,4]	70J @ 0°C – Average of three tests 50J @ 0°C – Individual test	No special seismic provisions apply

Notes.

1. The limits in item 1 are based on grade reference steel thickness of $12<t\leq 20$mm from the appropriate material supply standard.
2. For items 2, 3 and 4, the mechanical properties are those recorded on the certified mill test report or test certificate.
3. Charpy V-notch testing is only required for sections greater than 12mm thick.
4. These impact energy requirements are only for steels in environments where the basic service temperature is ≥5°C.

From *NZS 3404* by Standards New Zealand, 1997. Copyright 1997 by Standards New Zealand.

The seismic material requirements are intended to:

- Suppress brittle fracture of steels subject to inelastic demand and a high strain rate associated with seismic loading (see Table 12.4, item 5)
- Ensure ductile behavior through minimum tensile elongation, maximum f_y/f_u ratio and grade yield stress requirements (see Table 12.4, items 2,3 and 1 respectively)
- Limit member over strength capacity to ensure the strength hierarchy assumed in the capacity design process is maintained (see Table 12.4, item 4).

Compliance with the requirements of Table 12.4 is established from the data on a material test certificate. After publication of the latest material requirements for seismic applications in NZS 3404, a seismic steel grade S0 was introduced to the hot-rolled and plate standards AS/NZS 3679.1 and AS/NZS 3678 respectively. This steel is a deemed to comply with product manufactured to the requirements of Table 12.4.

NZS 3404 limits the use of cold-formed hollow sections in seismic applications. Such sections must not be used as category 1 members. Additionally, they must not be used as category 2 members unless their ductility capacity is established by testing or rational analysis (SNZ, 1997a). In practice, this limits the use of cold-formed hollow sections to category 3 and 4 members (Fussell, Cowie, Clifton and Karpenko, 2020).

2.3 Acceptance of Steels

According to NZS 3404, a certified mill test report or test certificate issued by the steel mill constitutes sufficient evidence of compliance with the material supply standard.

An additional requirement of the AS/NZS product standards is that the tests performed on behalf of the manufacturer must be undertaken by a laboratory that is accredited by a signatory to the International Laboratory Accreditation Corporation (ILAC) Mutual Recognition Agreement (MRA) for the specific tests described in the standard (SA/SNZ, 2016b).

3.0 Overview of EN 10219

3.1 Scope

EN 10219 specifies requirements for cold-formed welded circular, square and rectangular hollows sections for structural applications.

Technical delivery conditions are specified in EN 10219-1, while dimensions, tolerances and section properties are specified in EN 10219-2.

3.2 Delivery Conditions

Delivery Condition	Quality
As rolled or normalised/normalised rolled	JR, JO, J2, K2
Normalised/normalised rolled	N, NL
Thermomechanically rolled	M, ML

Note. Refer to Appendix B for a discussion of the steel making techniques used to manufacture steels in the as-rolled, normalised and thermomechanically rolled conditions. Adapted from *Cold formed welded structural hollow sections of non-alloy and fine-grained steels – Parts 1&2, EN 10219* by CEN, 2006. Copyright 2006 by CEN.

3.3 Steel Making Processes

The steel making process is at the discretion of the steel producer.

3.4 Manufacturing Processes

- Electric resistance welding – longitudinal welded
- Submerged arc welding – longitudinal or spiral welded

3.5 Steel Grades and Mechanical Properties

3.5.1 Non-alloy Hollow Sections

Table 2

Mechanical properties of non-alloy steel hollow sections in thicknesses ≤ 40mm

Steel grade	Minimum yield strength R_{eH} MPa		Tensile strength R_m MPa		Minimum elongation A[d] %	Minimum impact energy KV[e] J			Steel Type
	Specified thickness mm		Specified thickness mm		Specified thickness mm	at test temperature of			
	≤ 16	> 16 ≤ 40	< 3	≥ 3 ≤ 40	≤ 40	-20°C	0°C	20°C	
S235JRH[a]	235	225	360-510	360-510	24[b]			27	1
S275J0H[a]	275	265	430-580	410-560	20[c]		27		2
S275J2H						27			3
S355J0H[a]	355	345	510-680	470-630	20[c]		27		5
S355J2H						27			6
S355K2H						40[f]			6

Notes.

a Impact properties are verified only when this purchasing option is specified.

b For thicknesses > 3mm and section sizes D/T < 15 (round) and (B+H)/2T < 12.5 (square and rectangular), the minimum elongation is reduced by 2. For thicknesses ≤ 3mm the minimum value for elongation is 17%.

c For section sizes D/T < 15 (circular) and (B+H)/2T < 12.5 (square and rectangular), the minimum elongation is reduced by 2.

d For thicknesses < 3mm, the percentage elongation reported may be for a gauge length of 50mm or 80mm.

e For impact properties for reduced section test pieces, the minimum impact values must be reduced in direct proportion to the width of the test sample to that of the standard test sample.

f This value corresponds to 27J at -30°C.

g Impact testing is not required for material thickness < 6mm.

3.5.2 Hollow Sections with Feedstock Material Condition N

Table 3

Mechanical properties for hollow sections in thicknesses ≤ 40mm with feedstock condition N

Steel grade	**Minimum yield strength** R_{eH} MPa		**Tensile strength** R_m MPa	**Minimum elongation** A [a b] %	**Minimum impact energy** KV^c J		**Steel type**
	Specified thickness mm		**Specified thickness** mm	**Specified thickness** mm	at test temperature of		
	≤ 16	> 16 ≤ 40	≤ 40	≤ 40	-50°C	-20°C	
S275NH	275	265	370-510	24		40[d]	3
S275NLH					27		3
S355NH	355	345	470-630	22		40[d]	6
S355NLH					27		6
S460NH	460	440	540-720	17		40[d]	7C
S460NLH					27		7C

Notes.

From *Cold formed welded structural hollow sections of non-alloy and fine-grained steels – Parts 1&2, EN 10219* by CEN, 2006. Copyright 2006 by CEN.

a For section sizes D/T < 15 (circular) and (B+H)/2T < 12.5 (square and rectangular), the minimum elongation is reduced by 2.

b For thicknesses < 3mm, the percentage elongation reported may be for a gauge length of 50mm or 80mm.

c For impact properties for reduced section test pieces, the minimum impact values must be reduced in direct proportion to the width of the test sample to that of the standard test sample.

d This value corresponds to 27J at -30°C.

e Impact testing is not required for material thickness < 6mm.

3.5.3 Hollow Sections with Feedstock Material Condition M

Table 4
Mechanical properties for hollow sections in thicknesses ≤ 40mm with feedstock material condition M

Steel grade	Minimum yield strength R_{eH} MPa		Tensile strength R_m MPa	Minimum elongation *A* [a b] %	Minimum impact energy ***KV***[c] J		Steel type
	Specified thickness mm		Specified thickness mm	Specified thickness mm	at test temperature of		
	≤ 16	> 16 ≤ 40	≤ 40	≤ 40	-50°C	-20°C	
S275MH	275	265	360-510	24		40[d]	3
S275MLH					27		3
S355MH	355	345	450-610	22		40[d]	6
S355MLH					27		6
S420MH	420	400	500-660	19		40[d]	7C
S420MLH					27		7C
S460MH	460	440	530-720	17		40[d]	7C
S460MLH					27		7C

Notes.

a For section sizes D/T < 15 (circular) and (B+H)/2T < 12.5 (square and rectangular) the minimum elongation is reduced by 2.

b For thicknesses < 3mm the percentage elongation reported may be for a gauge length of 50mm or 80mm.

c For impact properties for reduced section test pieces the minimum impact values must be reduced in direct proportion to the width of the test sample to that of the standard test sample.

d This value corresponds to 27J at -30°C (see EN 1993-1).

e Impact testing is not required for material thickness < 6mm.

From *Cold formed welded structural hollow sections of non-alloy and fine-grained steels – Parts 1&2, EN 10219* by CEN, 2006. Copyright 2006 by CEN.

3.6 Inspection Documentation

The inspection document requirements for cold-formed hollow sections manufactured to EN 10219 are as follows:

- Non-alloyed steel hollow sections of qualities JR and J0 shall be supplied with a type 2.2 test report unless a type 3.1 or 3.2 test report is specified. Refer to Appendix C for an explanation of inspection types.

- Non-alloyed steel hollow sections of qualities J2 and K2 and fine-grain hollow sections of qualities M, ML, N and NL shall be supplied with a type 3.1 test report unless a type 3.2 is specified.
- The key differences in the inspection document requirements between EN 10219 and AS/NZS 1163 relate to reporting boron, test facility accreditation and inspection documentation type. Refer to Appendix H for further details.

3.7 Conformity Evaluation Requirements

The conformity of steel hollow sections to the requirements of the standard are established by:

- Initial Type Testing (ITT): The complete set of tests described in a standard to determine the characteristics of samples of product representative of the product type. The ITT provides the manufacturer with the characteristics of the product using their manufacturing, measuring and quality management system (QMS) (Hicks, 2016).
- Factory Production Control (FPC): Operational techniques and all measures necessary to maintain and regulate the conformity of the product to the requirements of the relevant standards, which ensure that performance declared by the manufacturer (through ITT) continues to be valid for all subsequent products. This includes personnel equipment, procedures and inspection, and testing (Hicks, 2016).

A point to note concerning testing is that the impact properties of hollow sections with steel qualities JR and JO are not verified by testing, unless such testing is specified by the purchaser (CEN, 2006).

3.8 Independent Assessment of Manufacturer Capability

European Construction Product Regulations define the degree of involvement of a third party (Notified Bodies) in assessing the conformity of structural steels manufactured to EN product standards. The key role for a Notified Body is auditing and certifying that the FPC system of the manufacturer meets the requirements of the relevant product standard (Annex ZA). For a list of accredited notified bodies, refer to: http://ec.europa.eu/growth/tools-databases/nandol/. The requirement for a manufacturer to have their FPC system certified is only applicable if their product is supplied into the European Union.

3.9 Markings

Product is marked by the manufacturer to provide details of the section (designation, manufacturer's name or trademark, and document identification number which correlates the product to the inspection document). Products may be marked individually or in bundles.

3.10 Comparison with AS/NZS 1163

Structural hollow sections for New Zealand building and infrastructure projects are typically supplied to AS/NZS 1163 (SA/SNZ, 2016a). For a comparison of the requirements of AS/NZS 1163 and EN 10219, refer to Appendix H.

4.0 Using EN 10219 with NZS 3404

4.1 Introduction

This section will discuss how to use the NZS 3404 design rules with steels manufactured to EN 10219. It also addresses material selection to avoid brittle fracture and the welding of such sections.

4.2 Design Parameters

4.2.1 Yield Stress

The yield stress (f_y) used for design should not exceed that given in Tables 2, 3 or 4 (R_{eH} – dependent on feedstock delivery condition).

For rolled sections, the specified thickness of the thickest element of the cross section shall be used.

4.2.2 Tensile Strength

The tensile strength used for design (f_u) should not exceed that given in Tables 2, 3 or 4 (R_m – dependent on feedstock delivery condition).

For rolled sections, the specified thickness of the thickest element of the cross section shall be used.

4.3 Design Aids

To assist designers to efficiently design steel elements using sections manufactured to EN 10219, design aids consisting of design section property tables and design software have been prepared.

4.3.1 Design Section Property Tables

Design section property tables have been prepared for a limited range of sections manufactured to EN 10219, see Appendix F. These tables include the following properties:

Geometric Properties

1. Area (A)
2. Second moment of inertia (I)
3. Elastic modulus (Z)
4. Plastic modulus (S)
5. Radius of gyration (r)
6. Torsion constant (T)
7. Torsion modulus (C)

Properties for design to NZS 3404

1. Form factor (K_f)
2. Effective section modulus (Z_e)
3. Compactness designation (compact, non-compact, slender)

4.3.2 Design Software

The New Zealand Structural Engineering Society (SESOC) has made available a suite of design software for their members. The database of their steel design software, MEMDES, has been extended to include a limited range of sections and grades to EN 10219. To download the latest version of MEMDES with the extended section database, visit the SESOC website.

5.0 Welding of EN 10219 Steel to AS/NZS 1554.1

NZS 3404 specifies that all welding is to comply with AS/NZS 1554.1. The welding requirements of this standard were developed for Australian manufactured steels. In particular, the preheat determination method was linked to a range of AS/NZS steel grades known as prequalified materials (Weld Australia, 2019). Non-prequalified steels, such as those manufactured to EN 10219, may be welded in accordance with AS/NZS 1554.1 subject to the following requirements:

- Verification of the preheat requirement
- Matching of the parent material to a welding consumable
- Qualification of the welding procedure. Note, additional mechanical tests are required to qualify weld procedures for non-prequalified steels.

Additional information concerning the welding of non-prequalified steels is presented in Appendix D and the HERA Welding Centre Notice, Welding of non-AS/NZS steels to AS/NZS 1554.1 (HERA, 2017).

6.0 Material Selection

6.1 Introduction

The material selections to avoid brittle fracture provisions of NZS 3404 have limited applicability to steels manufactured to EN 10219 for several reasons. Firstly, steels manufactured to this standard are not included in the steel type relationship to Steel Grade Table 2.6.4.4 (NZS 3404). Secondly, the material selection provisions in NZS 3404 are based on test data for Australian manufactured steels and are not considered reliable for non-Australian steels (AS/NZS 1554.1, Table B1, Note 2 (SA/NZS, 2014)). Another limitation of the material selection provisions in NZS 3404 is that they do not account for bending strain introduced during manufacturing of circular and square hollow sections (Feldmann et al., 2012). Consequently, this procedure can be non-conservative, especially with regards to square and rectangular hollow sections.

An alternative material selection approach to that presented in NZS 3404 has been developed by Hobbacher and Karpenko (2020). This approach, which is based on EN 1993-1-10 (CEN, 2005) and the JRC-ECCS 72702 report (Feldmann et al., 2012), has been developed for seismic and non-seismic applications. It is generally applicable to a variety of structural steels, including non-Australian manufactured steels and steels manufactured to international steel standards. The methodology of Hobbacher and Karpenko is recommended to select EN 10219 steels for non-seismic applications. The reason for this limitation is discussed in Section 6.2. The step-by-step implementation of the methodology is discussed in Section 6.4.

6.2 Scope

The use of EN 10219 cold-formed hollow sections for seismic applications is outside the scope of this Guide. As noted in Section 2.2, NZS 3404 limits the use of cold-formed hollow sections to category 3 and 4 members for seismic applications. Such sections do not meet the NZS 3404 category 3 seismic member material provisions. These requirements are considered overly onerous for category 3 members. SCNZ has published a discussion paper (Fussell et.al., 2020) recommending revised category 3 member material requirements. A copy of this paper is available for download from the SCNZ website. The intention is that this discussion paper will become the basis for changes to the current category 3 member material selection criteria. These revised material selection criteria, which are based on the NZS 3404.1:2009 provisions (SNZ, 2009), will allow for a range of cold-formed hollow section steel grades to be used as category 3 members.

Notwithstanding the inability of cold-formed hollow sections to meet the current category 3 member material requirements of NZS 3404, such sections are commonly used as members in seismic-resisting systems. For selection of cold-formed hollow section for seismic application enquiries, contact SCNZ.

6.3 Status

The material selection to avoid brittle fracture methodology recommended in this Guide is outside the scope of NZS 3404 and is, therefore, an alternative solution for demonstrating compliance with the Building Code.

6.4 Summary of Material Selection Methodology

6.4.1 General

The step-by-step implementation of the material selection methodology in Hobbacher and Karpenko (2020) is presented in this section. This methodology is similar to the NZS 3404 notch ductile method. These similarities include determination of a design temperature, defined as the modified design service temperature to differentiate it from the design service temperature specified in NZS 3404 and the selection of acceptable steel grades from maximum permissible wall thickness at lowest service temperature tables.

The modified design service temperature is calculated as follows:

$$T_{Ed} = T_{md} + \Delta T_{\varepsilon,cf} + \Delta T_{\dot{\varepsilon}} + \Delta T_{\varepsilon,cf,EXC} \quad \text{(Eqn 1)}$$

Where:

T_{Ed} Modified design service temperature

T_{md} Design service temperature from NZS 3404 or AS/NZS 5100 (SA/SNZ, 2017)

$\Delta T_{\varepsilon,cf}$ Temperature shift due to cold forming of the hollow section

$\Delta T_{\dot{\varepsilon}}$ Temperature shift due to seismic strain rate

$\Delta T_{\varepsilon,cf,EXC}$ Temperature shift due to cold forming during fabrication/construction processes

Note, $\Delta T_{\varepsilon,cf}$, $\Delta T_{\dot{\varepsilon}}$ and $\Delta T_{\varepsilon,cf,EXC}$ are subtracted from the design service temperature, T_{Ed}. Alternatively, they can be added to the tabulated lowest service temperature values presented as a function of material thickness. This approach has been adopted in the maximum wall thickness at lowest service temperature selection tables in Hobbacher and Karpenko (2020) for cold-formed hollow sections. These tables already include a temperature shift to account for the residual stresses resulting from cold forming the section, $\Delta T_{\varepsilon,cf}$, based on conservative bend radii assumptions.

6.4.2 Steps

Step 1 Evaluate the design service temperature

Determine the design service temperature from the LODMAT (lowest one day mean ambient temperature) isotherms presented in Figure 2.6.3.1 (NZS 3404) or Section 14.4 (AS/NZS 5100.6), with modification according to 2.6.3.2 (if required).

Step 2 Compute the shift in temperature due to cold forming during the fabrication and construction process

If the steelwork is subject to cold forming during a fabrication or construction process, such as pre-cambering, use equation 18 in Hobbacher and Karpenko (2020). The plastic strain, ε_f, can be calculated using the methodology in clause C2.6 NZS 3404.2 (SNZ, 1997b).

Step 3 Compute acting design temperature

Compute the modified design service temperature, T_{Ed}, using equation 1.

Step 4 Select steel grade

Select an acceptable steel grade from the maximum wall thickness at the lowest permissible service temperature tables in Hobbacher and Karpenko (2020). The selection table for non-seismic applications is presented in Appendix G. An acceptable steel grade is one that satisfies the following criteria:

- The lowest service temperature is lower than the design service temperature, and
- The maximum permissible wall thickness must be greater than the actual wall thickness of the hollow section.

Worked examples presented in Appendix E illustrate the recommended material selection methodology.

7.0 Recommended Section Sizes and Grades

Tube makers are typically only rolling mills, which form and weld hot-rolled strip or coil supplied by another steel mill to produce structural hollow sections. This feedstock material is supplied in standard weights, consequently, minimum order quantities apply. Typical minimum order quantities (MOQ) are in the order of 10-25 tonnes, however, if uncommon sections are specified (grade and thickness of feedstock, and section size), and the order cannot be combined with other orders, a minimum order quantity of several hundred tonnes may apply.

To aid in procuring large-sized hollow sections to EN 10219, the following recommendations apply:

1. Contact a steel distributor prior to finalising section sizes to ascertain section availability.
2. Allow sufficient time in the steel procurement programme for sourcing large hollow sections, as such sections will not be supplied from the distributor's inventory. A lead-time of five to six months will usually apply from the time the product is ordered until it arrives by ship in New Zealand.
3. Specify more commonly available feedstock grades and thicknesses.
4. Limit section sizes to those not readily supplied to AS/NZS 1163.

A suggested range of EN 10219 hollow sections is presented in Table 5. Design section properties for this range of product are presented in Appendix F.

Table 5

Recommended range of EN 10219 sections

Product Type	Section Size	Wall Thickness	Grade
Circular hollow section (CHS)	508OD	6, 6.3, 8, 10, 12, 12.5, 16, 20, 25, 30	S355J0[1]
	610OD		
	711 OD		
	762 OD		
	813 OD	8, 10, 12, 12.5, 16, 20, 25, 30	
Rectangular Hollow Section (RHS)	300x100	6, 6.3, 8, 10, 12, 12.5, 16	
	300x150		
	300x200		
	350x250		
	400x200	8, 12.5, 16	
	400x300	8, 10, 12, 12.5, 16	
Square Hollow Section (SHS)	300	6, 6.3, 8, 10, 12, 12.5, 16	
	350	8, 10, 12, 12.5, 16	
	400	10, 12, 12.5, 16	

Note.

1. A steel grade with greater minimum Charpy impact toughness value may be required for seismic or low temperature applications.

An alternative option for sourcing large diameter pipes is product manufactured to the API 5L (API, 2018) specification. While API 5L pipe is primarily for the oil and gas industry, this product has been used for structural applications. It is often supplied as dual graded (API 5L and AS/NZS 1163) to the New Zealand market in diameters up to 610mm. This dual grading simplifies the building consent process as the design engineer does not need to justify the use of API 5L as this product is not recognised in NZS 3404 as a prequalified material specification.

Where API 5L pipe is used, an approval process is required to demonstrate that this product is compatible for use with the steel structures standard. Amongst other things, the approval process would need to establish that the material properties of this product are consistent with the assumptions made in the structural reliability exercise used to calibrate the NZS 3404 design rules. Such an approval process is an alternative solution for establishing compliance with the Building Code.

While API 5L pipe is outside the scope of this Guide, the recommendations in this document regarding design (Section 4.2), material selection (Section 6) and welding (Section 5) are applicable to API 5L pipe.

As noted above, for EN 10219 product, it is recommended that designers contact a steel distributor to establish the availability of API 5L product prior to finalising sizes and grades etc.

8.0 Establishing Compliance

With the globalisation of structural steel supply chains for New Zealand building and infrastructure projects, more robust procurement practices are required to demonstrate product conformity than is currently stipulated in NZS 3404 (Fussell et al., 2018). In NZS 3404, reliance is placed on a material test certificate as the primary means of establishing the compliance of steel with a product standard in spite of the fact that there have been examples of fraudulent test certificates for construction products.

In collaboration with HERA, and to address this reality, SCNZ has developed the *New Zealand Guide to the Sourcing of Compliant Structural Steels* (Fussell et al., 2018).

It is recommended that EN 10219 is specified with the following requirements:

1. Structural steels are sourced in accordance with the *Guide to the Sourcing of Compliant Structural Steels*.
2. Ideally, EN 10219 structural hollow sections should be sourced from a tube maker with their Factory Production Control system certified by a Notified Body as meeting the requirements of Appendix ZA of EN 10219. For a list of Notified Bodies, refer to: http://cc.europa.eu/growth/tools-databases/nando/

NB If product cannot be sourced from a tube maker with FPC certification, there is still a conformance assessment pathway for establishing the compliance of such product in the *Guide to the Sourcing of Compliant Structural Steels*. In practice, this will result in additional verification testing. The extent of such testing will depend on the project Construction Category.

9.0 Specifying EN 10219 Sections

There are differences in the EN 10219 testing and inspection document requirements and those found in the AS/NZS product standards. Recommended exemplar steelwork specification clauses to address these differences are as follows:

1 Material Test Certificates

i. A type 3.1 or 3.2 inspection document shall be supplied with the steel

ii. If the boron content is not specified on the material test certificate, the material shall be tested to determine the total boron content. Refer to *HERA advisory notice – Welding to AS/NZS 1554.1 with boron containing steels* for appropriate boron test procedures.

2 Test Facility Accreditations

Testing shall be undertaken by a test facility accredited by an International Laboratory Accreditation Corporation Mutual Recognition Agreement signatory for the test procedures specified in EN 10219.

3 Impact Property Testing

The impact properties of cold-formed hollow sections manufactured to EN 10219 with steel quality J0 shall be verified by testing.

4 Welding EN 10219 Steels

The weld procedure for steels manufactured to EN 10219 shall be qualified in accordance with the non-prequalified parent material provisions of AS/NZS 1554.1 and the *Welding Centre Notice – Welding of non-AS/NZS steels to AS/NZS 1554.1.*

NB Items 1(ii), 2 and 3 may result in the Steel Distributor having to undertake testing on the product at an appropriately accredited independent test facility. It is important that these requirements are included in the tender documents to ensure the cost and time implications of such requirements are known in advance by parties bidding for the contract.

References

API. (2018). *Line pipe, API specification 5L* (46th ed.). Americal Petroleum Institute.

CEN. (2001). *Welding. Recommendation for welding of metallic materials* (BS EN 1011-2). European Committee for Standardization.

CEN. (2004). *Metallic products – types of inspection documents* (EN 10204). European Committe for Standardization.

CEN. (2005). *Design of steel strucures – Part 1-10: Material toughness and through-thickness properties* (EN 1993-1-10). European Committeee for Standardization.

CEN. (2006). *Cold formed welded structural hollow sections of non-alloy and fine grain steels* (EN 10219). European Committee for Standardization.

Chung, K. F., Chiew, S. P., & Lee, H. Y. (2015). *Selection of equivalent steel materials to European steel materials specifications: Professional guide HKCMSA-P001*. Hong Kong Constructional Metal Structures Association; Macau Society of Metal Structures; Chinese National Engineering Research Centre for Steel Construction. https://www.polyu.edu.hk/cnerc-steel/images/publications/Selection-of-Equivalent-Steel-Materials-to-European-Steel-Materials-Specifications.pdf

Feldmann, M., Eichler, B., Kühn B., Stranghöner N., Dahl W., Langenberg P., Kouhi J., Pope R., G. Sedlacek, G., Ritakallio P., Iglesias G., Puthli, R.S., Packer J.A., & Krampen, J. (2012). *Choice of steel material to avoid brittle fracture for hollow section structures:* JRC-ECCS 72702. Joint Research Centre (JRC). https://tinyurl.com/y7ddyqpb

Fussell, A., Cowie, K., Hicks, S., & Karpenko, M. (2018). *New Zealand guide to the sourcing of compliant structural steels* [Report] (111:2018). Steel Construction New Zealand (SCNZ). https://tinyurl.com/ybxv2qpu

Fussell, A., Cowie, K., Clifton, C. & Karpenko M. (2020). *Proposed material requirements for category 3 members in seismic-resisting systems* (Steel Advisor MAT 2002). SCNZ.

HERA. (2017). *Welding of non-AS/NZS steels to AS/NZS 1554.1* [Notice]. https://www.hera.org.nz/welding-non-asnzs-steels-asnzs1554-1/

Hicks, S. (2016). Conformity of structural steel products and structures. *SESOC Journal, 29*(2), 14-18.

Hobbacher, A., & Karpenko, M. (2020). *Provisions for avoiding brittle fracture in steels used in Australasia*. International Institute of Welding.

Karpenko, M., Hicks, S., Fussell, A., & Wilcox, P. (2017). *Welding to AS/NZS 1554.1 of boron containing steel [Advisory notice].* Heavy Engineering Research Association (HERA). https://www.hera.org.nz/wp-content/uploads/HERAAdvisoryNotice_WeldingToASNZS1554.1BoronContainingSteel_2017.pdf

SA. (1998). *Steel structures* (AS 4100-1998). Standards Australia.

SA/SNZ. (2014). *Structural steel welding - Part 1: Welding of steel structure, incorporating amendments no. 1 & 2*. Standards Australia; Standards New Zealand.

SA/SNZ. (2016a). *Cold-formed structural hollow sections* (AS/NZS 1163). Standards Australia; Standards New Zealand.

SA/SNZ. (2016b). *Hot-rolled bars and sections* (AS/NZS 3679.1). Standards Australia; Standards New Zealand.

SA/SNZ. (2016c). *Structural steel – hot-rolled plates, floor plates and slabs* (AS/NZS 3678). Standards Australia; Standards New Zealand.

SA/SNZ. (2016d). *Structural steel welding - Part 2: Welded I sections* (AS/NZS 3679-2). Standards Australia; Standards New Zealand.

SA/SNZ. (2016e). *Structural steelwork – Fabrication and erection* (AS/NZS 5131:2016). Standards Australia; Standards New Zealand.

SA/SNZ. (2017). *Bridge design: Part 6: Steel and composite construction*. Standards Australia; Standards New Zealand.

SNZ. (1997a). *Steel structures standard, including amendments: Part 1* (NZS 3404). Standards New Zealand.

SNZ. (1997b). *Steel structures standard, including amendments: Part 2* (NZS 3404). Standards New Zealand.

SNZ. (2009). *Steel structures standard: Part 1* (NZ 3404.1). Standards New Zealand.

Weld Australia. (2017). A guide to understanding AS/NZS 1554.1 [Technical Guidance Note]. https://weldaustralia.com.au/wp-content/uploads/2019/02/Weld-Australia-Guidance-Note-TGN-SG04-Understanding-AS-NZS-1554-1.pdf

Appendices

Appendix A Steel Standards Recognised in NZS 3404.1:1:1997

(a) Australian or Joint Australian/New Zealand Standards:

AS/NZS 1163	Structural steel hollow sections
AS 1594	Hot-rolled steel flat products
AS/NZS 3678	Structural steel – Hot-rolled plates, floorplates and slabs
AS/NZS 3679	Structural steel
Part 1	Hot-rolled bars and sections
Part 2	Welded I-sections

(b) British Standards:

BS4	Structural steel sections
Part1	Specification for hot-rolled sections
BS 4848	Hot-rolled structural steel sections
Part 2	Specification for hot-finished hollow sections
Part 4	Equal and unequal angles
BS 7668	Weldable structural steels. Hot-finished structural hollow sections in weather-resistant steels. Specification
BS EN 10025	Hot-rolled products of structural steels
Part 1	General delivery conditions
Part 2	Technical delivery conditions for non-alloy structural steels
Part 3	Technical delivery conditions for long products
Part 4	Technical delivery conditions for the thermomechanically rolled weldable fine-grain steels
Part 5	Technical delivery conditions for structural steels with improved atmospheric corrosion resistance
Part 6	Technical delivery conditions for plates and wide flats of high yield strength structural steels in the quenched and tempered condition
BS EN 10029	Specification for tolerances on dimensions, shape and mass for hot-rolled steel plates 3mm thick or above
BS EN 10210	Hot-finished structural hollow sections of non-alloy and fine-grain structural steels
Part 1	Technical delivery conditions
Part 2	Tolerances, dimensions and sectional properties
BS EN 10219	Cold-formed welded structural hollow sections of non-alloy and fine-grain steels
Part 1	Technical delivery conditions
Part 2	Tolerances, dimensions and sectional properties

(c) Japanese Standards:

JIS G 3101	Rolled steel for general structure
JIS G 3106	Rolled steel for welded structure
JIS G 3114	Hot-rolled atmospheric corrosion-resisting steels for welded structure
JIS G 3132	Hot-rolled carbon steel strip for pipes and tubes
JIS G 3136	Rolled steel for building structure
JIS G 3141	Cold-reduced carbon steel sheets and strip
JIS G 3192	Dimensions, mass and permissible variations of hot-rolled steel sections
JIS G 3193	Dimensions, mass and permissible variations of hot-rolled steel plates, sheets and strip

Note. From *Steel structures standard, AS/NZS 3404 including amendments: Part 1* by SNZ, 1997.

Appendix B Mechanical Working and Heat Treatment of Steels

The mechanical working of steel is commonly achieved through rolling (Chung et al., 2015). Such rolling increases the yield strength and decreases the ductility of the material.

Several production processes or rolling regimes are employed by steel makers. These are:

As Rolled

This is steel which has not been subject to some form of heat treatment during rolling. The typical rolling finish temperature is 750°C. As-rolled steel is denoted by “AR”.

Normalised

The as-rolled material is heated up to approximately 900°C and held at that temperature for a specific time before being allowed to cool naturally.

The process of normalising refines the grain size and improves the mechanical properties of the steel materials, including toughness. It also removes residual rolling strains. Normalised and normalised rolled steel are denoted with “N”.

Thermomechanically Rolled

Thermomechanically rolled steels have a different chemistry to as rolled and normalised. The chemical composition of such steels allows a rolling finish temperature below 700°C. Thereafter the steel is cooled naturally. Greater force is often required to roll steel at these temperatures. Thermomechanically rolled steel is denoted as “M”.

Quenched and Tempered

The process of quenching and temperature starts with normalised steel heated to 900°C. The steel is then rapidly cooled (quenched). This process produces steels with high strength and hardness but low toughness. The toughness is restored by reheating the steels to 600°C and maintaining this temperature for a specific period, then allowing it to cool naturally [tempering]. Such steels are denoted as “Q” or “QT”.

For a fuller discussion of these steel making processes, refer to the publication *Selection of Equivalent Materials to European Steel Material Specifications* (Chung et al., 2015).

Appendix C Inspection Documents

The types of inspection documents specified in EN 10204 (CEN, 2004) are described in Table C1.

Table C1

Summary of inspection document requirements

EN 10204	Inspection Type[1]	Document Content	Document Validated by
2.1	Non-specific	• Statement of compliance with the order • No test results	
2.2	Non-specific	• Statement of compliance with the order • Results of non-specific inspection	
3.1[2]	Specific	• Statement of compliance with the order • Results of specific inspection	The manufacturer's authorised inspection representative independent of the manufacturing department
3.2	Specific	• Statement of compliance with the order • Results of specific inspection	The manufacturer's authorised inspection representative independent of the manufacturing department and either: • The purchaser's authorised inspection representative or • The inspector designated by the official regulations

Notes.

1. Refer to section 1.6 for definitions of non-specific and specific inspection.

2. The inspection document requirements of the AS/NZS steel product standards would constitute type 3.1 inspection documents.

Appendix D Qualifying Welding Procedures for EN 10219 Steels

D.1 General Considerations for the Welding of International Standard Steel to AS/NZS 1554.1

In this section, recommendations are given for the welding of international standard steel, also called "non-prequalified" or "alternative" steel in accordance with AS/NZS 1554.1 (SA/SNZ, 2014). From a welding perspective, these steels are defined as parent materials not listed in AS/NZS 1554.1, Section 2.1, Item (c). This guideline should be used with the above standard if there are no manufacturer's recommendations.

This guideline allows the use of the existing welding procedures, provided qualification tests have been performed on representative butt welds and the other conditions of this guideline are met.

Welding requirements of AS/NZS 1554.1 were originally developed for steels manufactured in Australia. Imports of steel manufactured to other than AS/NZS standards have increased and, although often similar, have not necessarily been manufactured in accordance with the principles and requirements detailed in the AS/NZS steel standards. This means these steels should be welded in accordance with the manufacturer's recommendations or to the welding standard(s) of the country of origin. In the situation where no manufacturer's recommendations are available, the procedure set out in this guideline can be followed.

Care should be taken when applying AS/NZS 1554.1 preheat calculation procedures to international standard steels as they may require higher preheat than an "equivalent" steel listed in Section 2.1 AS/NZS 1554.1. Welding procedures should be qualified by testing to confirm the suitability of the proposed procedure.

Continuous production monitoring based on the requirements of AS/NZS 5131 Construction Category CC2 or higher should be implemented and selected non-destructive examination (NDE) should be used to confirm suitability of the welding procedure in production.

Welding procedure tests to AS/NZS 1554.1 are unlikely to reveal susceptibility of the steel to hydrogen cracking. Therefore, for butt welds in thick plates in critical applications with high restraint, it is recommended to apply higher preheat than that estimated using the AS/NZS 1554.1 procedures (Section 5.3). The recommended increase in preheat temperature for butt welds ranges from approximately 30°C for a butt joint with a combined thickness of up to 90mm to 50°C for larger thicknesses. Alternatively, the BS EN 1011-2 (CEN, 2001) Appendix C CET method can be used to estimate preheat. A hydrogen-controlled welding procedure shall be used for all critical applications.

The NDE of a weld (other than visual scanning and examination) shall not be completed before the minimum hold time after welding, as shown in AS/NZS 5131 Table 13.6.2.1.

The required through-thickness ductility of steel to resist lamellar tearing within a given joint configuration should be estimated following the procedure given in Appendix H of AS/NZS 1554.1:2014. Through-thickness ductility tests may be required to establish properties of the steel, depending on the outcome of the assessment. Ultrasonic examination of structural steel in the vicinity of critical welded details, such as cruciform joints transmitting tensile forces, bearing diaphragms or stiffeners, can be required to ensure there are no lamellar tearing defects after welding.

Any issues related to boron-containing steels should also be addressed in addition to the above considerations. Please refer to the *HERA advisory notice – welding to AS/NZS 1554.1 of boron containing steel* for details (Karpenko et al., 2017).

D.2 Requirements for Materials

The following conditions shall be fulfilled before qualifying alternative steel for structural under this guideline:

1. Parent materials used shall be grades as listed in this Guide (see Tables 2, 3 and 4).
2. Steel subject to welding shall have minimum Charpy V-notch toughness of 27 J at 20°C.
3. The grade of steel and welding consumables shall be selected with sufficient toughness, taking into account the service temperature, thickness of structural members and service conditions.
4. The specified impact toughness requirements also apply in the heat-affected zone (HAZ) of welded connections and it is recommended that the steel is ordered with sufficient safety margin.
5. The steel shall have adequate through-thickness ductility (Z-value) for the application considered in order to avoid lamellar tearing (if required).
6. Chemical composition of the steel (heat analysis) shall be reported on the material test certificate and comply with the limits of the applicable standards.
7. Welding consumables shall be matched with the steel type of the alternative steel in accordance with Table 4.6.1(A) of AS/NZS 1554.1 and used within the welding parameter ranges specified by the manufacturer. The steel type for the alternative steels can be found in Tables 2, 3 and 4 of this Guide. In addition, the impact test temperature of the consumables (as specified in the relevant standard for the consumables) shall not be warmer than the design service temperature for the structure.
8. The welding consumables selected shall match or overmatch minimum yield strength of the parent materials. It is achieved by matching welding consumables with the steel types as per Item 7 above and selecting the welding consumable with the highest tensile strength designation in the applicable cell of the AS/NZS 1554.1 Table 4.6.1(A) e.g. AS/NZS ISO 17632 B-T493U for the steel type 3. Consumables prequalified for steel type 7C are prequalified for use on other steel types listed in this Guide.
9. Hydrogen-controlled welding consumables/procedure shall be used.
10. Steel shall not contain total boron equal to or exceeding 0.0008%.
11. "Heavy" metals such as bismuth, lead, selenium and tellurium should not be present in structural steels as they are known to cause issues with grain boundary precipitates.

D.3 Requirements for Qualification Tests

To qualify welding procedures for steel that comply with the above conditions, the following steps shall be adhered to:

1. In order to establish a weldability group number (AS/NZS 1554.1, Section 5.3.4a), calculate the carbon equivalent (CE) or read it from the certificate (provided the same CE equation has been

used) and add 0.02 to the value. Then select the Weldability Group Number from AS/NZS 1554.1 Table 5.3.4(B).

2. The established weldability group number should be equal to or lower than Group Number 6, Table 5.3.4(B), AS/NZS 1554.1. Steel products with the weldability Group Number 7 or higher should be welded in accordance with the manufacturer's recommendations or to the welding standard(s) of the country of origin. The qualification test piece should use representative plate(s) with the highest CE value. The thickness range qualified shall be to AS/NZS 1554.1 Table 4.11.8(A).
3. The tests should follow a draft (preliminary) welding procedure specification (pWPS) or procedure qualification record (PQR). This also includes preheat requirements (if any) as established in accordance with AS/NZS 1554.1 and the above recommendations.
4. Welding procedure shall be qualified by testing. Qualification tests shall follow the testing requirements for non-prequalified materials in accordance with AS/NZS 1554.1 Table 4.7.1. In addition, Charpy impact tests shall be performed in the heat affected zone (HAZ) of the weld with a V-notch located next to the fusion line.
5. In addition, HAZ hardness tests to AS/NZS 1554.1 Section 4.7.9 shall be carried out to confirm adequate preheat. The hardness tests shall be performed in the cross-section of the weld HAZ in the vicinity of the weld face and root.
6. The testing temperature, test requirements (including direction of the test in relation to the direction of rolling – longitudinal or transverse), and acceptance criteria for the Charpy impact tests performed in the HAZ, shall be as per product standard or equivalent AS/NZS steel grade standard. In light of the influence that directionality has on the Charpy impact test, all test material shall be clearly marked with the direction of rolling to ensure that the joint preparation and all subsequent test samples are in the correct orientation.

D.4 Requirements for the Use of Existing Welding Procedures

Subject to a representative butt weld WPS(s) for an international standard steel being qualified by testing (see previous section), existing welding procedures can be revised for the use on that steel to cover fillet welds and other butt welds. The following applies:

1. An existing WPS for fillet welds can be used for international standard steel, provided <u>at least one butt weld</u> has been qualified for that steel in accordance with this guideline.
2. The existing welding procedures shall have an equal or higher weldability group number than that of the international standard steel considered.
3. The existing welding procedures shall be revised to specify the international standard steel. They also include preheat requirements that shall be based on a butt-weld procedure, whichever is higher. The procedure shall be approved by a Responsible Welding Coordinator with a qualification such as AS/NZS 2214 Welding Supervisor as a minimum.
4. Preheat requirements shall be listed on the welding procedure as a function of combined plate thickness i.e. general requirements such as "Preheat may be required" do not provide the necessary control of welding conditions.

5. If the weldability group number of the proposed international standard steel is higher than that used in the existing welding procedure for the fillet weld, the welding procedure shall be qualified based on a butt weld as per Section D.3.
6. The heat input specified in an existing weld procedure specification (WPS) shall not exceed that of the WPS qualified for the international standard steel according to Section D.3.
7. If the heat input specified in any existing WPS to be used on the project is lower than the minimum allowed in the WPS for the alternative steel, an additional qualification test should be performed using the lowest heat input. This additional welding procedure can be qualified by the hardness test only.

D.5 Fabrication Requirements

The following applies for production welds:

1. All welding shall comply with the requirements of AS/NZS 5131 Construction Category CC2 or higher.
2. The quantity of inspection and non-destructive examination (NDE) should be in accordance with AS/NZS 5131 Appendix I.
3. Post-welding NDE shall be performed on at least the first five butt-welded joints, where the new procedure is used for production welding for the first time. The NDE shall include ultrasonic testing and surface crack detection by magnetic particle or liquid penetrant testing. Inspection performed on thicker plates shall cover thinner plates but not vice versa. Ultrasonic testing is not required for fillet welds.
4. Post-welding NDE should be routinely considered for butt-welded plates with thickness of 60mm or greater.
5. In accordance with AS/NZS 5131 Section 13.6.2.1, the NDE of a weld (other than visual examination) shall not be completed until after the minimum hold time after welding.

D.6 Test Failure

Failure to pass a procedure test or production NDE test can be an indication that steel requires a higher preheat than that calculated to AS/NZS 1554.1 and/or other welding issues. In this case, specialist welding/metallurgist advice is required.

Appendix E Material Selection Example

Project: Carparking building located in Queenstown

Element: Gravity columns – 400x400x12.5 SHS grade S355

Consider pre-strained (assume ε_{cf}=10%) and non-pre-strained

Case 1 (no pre-strain)

Step 1 Determine design service temperature

T_{md}= -5°C (see Figure 2.6.3.1 NZS 3404)

Step 2 Compute the shift in temperature due to cold forming during the fabrication and construction process. No cold forming during fabrication and construction processes i.e. $\Delta T_{\varepsilon,cf,EXC}$= 0°C

Step 3 Compute the modified design service temperature

$$T_{Ed} = T_{md} + \Delta T_{\varepsilon,cf} + \Delta T_{\dot{\varepsilon}} + \Delta T_{\varepsilon,cf,EXC} = -5 + 0 = -5°\text{C}$$

$\Delta T\varepsilon^{\cdot} = 0$ (non-seismic application)

Step 4 Select steel grade

Select an acceptable steel grade from the maximum permissible material thickness at lowest service temperature table in Appendix G. For a wall thickness of 12.5mm, the lowest service temperature for the material is approximately -40°C for subgrade J0H. As the lowest service temperature for S355J0H is lower than the modified design temperature i.e. -40°C ≤-5°C, S355J0H material is appropriate for the project.

Case 2 (10% pre-strain)

Step 1 Determine basic design service temperature

T_{md}= -5°C (see Figure 2.6.3.1 NZS 3404)

Step 2 Compute the shift in temperature due to cold forming during the fabrication and construction

process.

$\Delta T_{\varepsilon,cf,EXC} = 3.\varepsilon_{cf} = -3x10$=-30°C

Step 3 Compute the modified design service temperature

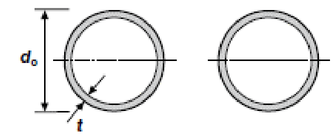
$$T_{Ed} = T_{md} + \Delta T_{\varepsilon,cf} + \Delta T_{\dot{\varepsilon}} + \Delta T_{\varepsilon,cf,EXC} = -5 - 30 = -35°\text{C}$$

Step 4 Select steel grade

S355J0H is also a suitable material as the lowest service temperature (-40°C) is lower than the modified design service temperature (-35°C).

Appendix F EN 10219 Section Design Properties

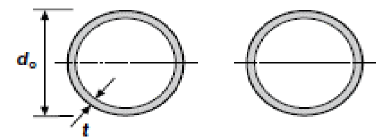
Circular Hollow Sections (CHS)
Dimensions and Properties
EN 10219 Grade S355



Dimensions and ratios								Properties							Properties for design to NZS 3404			
Designation				Mass per m	External Surface Area			Gross Section Area	About any axis				Torsion constant	Torsion modulus		Form factor	About any axis	
d_o	x	t			per m	per t	d_o/t	A_g	I	Z	S	r	J	C	f_y	k_f	Compactness	Z_e
mm		mm		kg/m	m^2/m	m^2/t		mm^2	$10^6\ mm^4$	$10^3\ mm^3$	$10^3\ mm^3$	mm	$10^6\ mm^4$	$10^3\ mm^3$	MPa		C,N,S	$10^3\ mm^3$
508	x	6.0	CHS	74	1.60	21.49	84.7	9462	298	1174	1512	177.5	596	2347	355	0.82	S	1173
		6.3	CHS	78	1.60	20.47	80.6	9930	312	1230	1586	177.4	625	2460	355	0.84	N	1258
		8.0	CHS	99	1.60	16.18	63.5	12566	393	1546	2000	176.8	786	3093	355	0.95	N	1740
		10.0	CHS	123	1.60	12.99	50.8	15645	485	1910	2480	176.1	970	3820	355	1.00	N	2300
		12.0	CHS	147	1.60	10.87	42.3	18699	575	2265	2953	175.4	1151	4530	355	1.00	N	2853
		12.5	CHS	153	1.60	10.45	40.6	19458	598	2353	3070	175.2	1195	4705	355	1.00	N	2991
		16.0	CHS	194	1.60	8.22	31.8	24731	749	2949	3874	174.0	1498	5898	355	1.00	C	3874
		20.0	CHS	241	1.60	6.63	25.4	30662	914	3600	4766	172.7	1829	7199	345	1.00	C	4766
		25.0	CHS	298	1.60	5.36	20.3	37935	1109	4367	5837	171.0	2218	8734	345	1.00	C	5837
		30.0	CHS	354	1.60	4.51	16.9	45050	1292	5086	6864	169.3	2583	10171	345	1.00	C	6864
610	x	6.0	CHS	89	1.92	21.44	101.7	11385	519	1702	2189	213.6	1038	3405	355	0.75	S	1552
		6.3	CHS	94	1.92	20.43	96.8	11948	544	1785	2296	213.5	1089	3570	355	0.77	S	1667
		8.0	CHS	119	1.92	16.14	76.3	15130	686	2248	2899	212.9	1371	4495	355	0.87	N	2357
		10.0	CHS	148	1.92	12.95	61.0	18850	848	2782	3600	212.2	1697	5564	355	0.97	N	3172
		12.0	CHS	177	1.92	10.83	50.8	22544	1008	3305	4292	211.5	2016	6611	355	1.00	N	3979
		12.5	CHS	184	1.92	10.40	48.8	23464	1048	3435	4463	211.3	2095	6869	355	1.00	N	4180
		16.0	CHS	234	1.92	8.18	38.1	29858	1318	4321	5647	210.1	2636	8641	355	1.00	N	5568
		20.0	CHS	291	1.92	6.59	30.5	37071	1615	5295	6965	208.7	3230	10589	345	1.00	C	6965
		25.0	CHS	361	1.92	5.31	24.4	45946	1969	6456	8561	207.0	3938	12912	345	1.00	C	8561
		30.0	CHS	429	1.92	4.47	20.3	54664	2305	7557	10101	205.3	4610	15113	345	1.00	C	10101

Notes
1. For grade S355; f_y=355 MPa for tube wall thickness t ≤ 16mm or f_y =345 MPa for 16mm < t ≤ 40mm; f_u = 470 Mpa where f_y and f_u are the yield stress and tensile strength respectively used in design to NZS 3404
2. C = compact section; N= non-compact section; S = slender section: as defined in NZS 3404
3. Cold formed hollow sections manufactured to EN 10219 have a residual stress classification of CF in NZS 3404

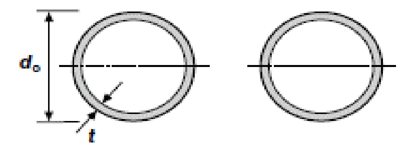
Circular Hollow Sections (CHS)
Dimensions and Properties
EN 10219 Grade S355



Dimensions and ratios									Properties							Properties for design to NZS 3404			
Designation				Mass per m	External Surface Area			Gross Section Area	About any axis				Torsion constant	Torsion modulus		Form factor	About any axis	
d_o	x	t			per m	per t	$\frac{d_o}{t}$	A_g	I	Z	S	r	J	C	f_y	k_f	Compactness	Z_e
mm		mm		kg/m	m^2/m	m^2/t		mm^2	$10^6 mm^4$	$10^3 mm^3$	$10^3 mm^3$	mm	$10^6 mm^4$	$10^3 mm^3$	MPa		C,N,S	$10^3 mm^3$
711	x	6.0	CHS	104	2.23	21.41	118.5	13289	826	2323	2982	249.3	1651	4645	355	0.70	S	1961
		6.3	CHS	109	2.23	20.40	112.9	13947	866	2436	3129	249.2	1732	4871	355	0.71	S	2108
		8.0	CHS	139	2.23	16.10	88.9	17668	1092	3071	3954	248.6	2183	6141	355	0.80	S	2994
		10.0	CHS	173	2.23	12.92	71.1	22023	1353	3806	4914	247.9	2706	7612	355	0.90	N	4107
		12.0	CHS	207	2.23	10.80	59.3	26352	1610	4529	5864	247.2	3220	9057	355	0.99	N	5213
		12.5	CHS	215	2.23	10.37	56.9	27430	1673	4707	6099	247.0	3347	9415	355	1.00	N	5487
		16.0	CHS	274	2.23	8.15	44.4	34935	2110	5936	7730	245.8	4221	11873	355	1.00	N	7394
		20.0	CHS	341	2.23	6.55	35.6	43417	2594	7295	9552	244.4	5187	14591	345	1.00	C	9552
		25.0	CHS	423	2.23	5.28	28.4	53878	3174	8927	11770	242.7	6347	17854	345	1.00	C	11770
		30.0	CHS	504	2.23	4.43	23.7	64183	3728	10486	13922	241.0	7456	20973	345	1.00	C	13922
762	x	6.0	CHS	112	2.39	21.40	127.0	14250	1018	2672	3429	267.3	2036	5345	355	0.67	S	2180
		6.3	CHS	117	2.39	20.39	121.0	14957	1068	2803	3598	267.2	2136	5605	355	0.69	S	2343
		8.0	CHS	149	2.39	16.09	95.3	18950	1347	3535	4548	266.6	2694	7070	355	0.78	S	3330
		10.0	CHS	185	2.39	12.91	76.2	23625	1670	4384	5655	265.9	3341	8768	355	0.87	N	4598
		12.0	CHS	222	2.39	10.79	63.5	28274	1989	5219	6751	265.2	3977	10439	355	0.95	N	5872
		12.5	CHS	231	2.39	10.36	61.0	29433	2067	5426	7023	265.0	4135	10852	355	0.97	N	6189
		16.0	CHS	294	2.39	8.13	47.6	37498	2610	6850	8906	263.8	5219	13699	355	1.00	N	8388
		20.0	CHS	366	2.39	6.54	38.1	46621	3211	8427	11014	262.4	6422	16855	345	1.00	N	10919
		25.0	CHS	454	2.39	5.27	30.5	57884	3935	10327	13584	260.7	7869	20654	345	1.00	C	13584
		30.0	CHS	542	2.39	4.42	25.4	68989	4629	12148	16084	259.0	9257	24297	345	1.00	C	16084

Notes
1. For grade S355; f_y=355 MPa for tube wall thickness t ≤ 16mm or f_y =345 MPa for 16mm < t ≤ 40mm; f_u = 470 Mpa where f_y and f_u are the yield stress and tensile strength respectively used in design to NZS 3404
2. C = compact section; N= non-compact section; S = slender section: as defined in NZS 3404
3. Cold formed hollow sections manufactured to EN 10219 have a residual stress classification of CF in NZS 3404

Circular Hollow Sections (CHS)
Dimensions and Properties
EN 10219 Grade S355

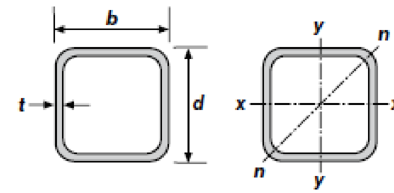


Dimensions and ratios								Properties							Properties for design to NZS 3404			
Designation				Mass per m	External Surface Area			Gross Section Area	About any axis				Torsion constant	Torsion modulus	Form factor		About any axis	
d_o	x	t			per m	per t	$\frac{d_o}{t}$	A_g	I	Z	S	r	J	C	f_y	k_f	Compactness	Z_e
mm		mm		kg/m	m^2/m	m^2/t		mm^2	10^6 mm^4	10^3 mm^3	10^3 mm^3	mm	10^6 mm^4	10^3 mm^3	MPa		C,N,S	10^3 mm^3
813	x	8.0	CHS	159	2.55	16.08	101.6	20232	1639	4032	5184	284.6	3278	8064	355	0.75	S	3677
		10.0	CHS	198	2.55	12.90	81.3	25227	2034	5003	6448	283.9	4067	10006	355	0.84	N	5097
		12.0	CHS	237	2.55	10.77	67.8	30197	2422	5959	7700	283.2	4845	11918	355	0.92	N	6551
		12.5	CHS	247	2.55	10.35	65.0	31436	2519	6196	8011	283.1	5037	12392	355	0.94	N	6913
		16.0	CHS	314	2.55	8.12	50.8	40062	3182	7828	10165	281.8	6364	15657	355	1.00	N	9425
		20.0	CHS	391	2.55	6.53	40.7	49826	3919	9641	12580	280.5	7838	19282	345	1.00	N	12324
		25.0	CHS	486	2.55	5.26	32.5	61889	4809	11829	15529	278.7	9617	23658	345	1.00	C	15529
		30.0	CHS	579	2.55	4.41	27.1	73796	5664	13933	18402	277.0	11327	27866	345	1.00	C	18402

Notes

1. For grade S355; f_y=355 MPa for tube wall thickness t ≤ 16mm or f_y =345 MPa for 16mm < t ≤ 40mm; f_u = 470 Mpa where f_y and f_u are the yield stress and tensile strength respectively used in design to NZS 3404
2. C = compact section; N= non-compact section; S = slender section: as defined in NZS 3404
3. Cold formed hollow sections manufactured to EN 10219 have a residual stress classification of CF in NZS 3404

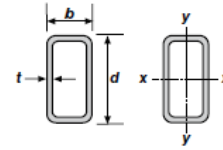
Square Hollow Sections (SHS)
Dimensions and Properties
EN 10219 Grade S355



Dimensions and Ratios								Properties							Properties for Design to NZS 3404		
Designation				Mass per m	External Surface Area			Gross Section Area	About any axis				Torsion constant	Torsion modulus	Form factor	About any axis	
d	b	t			per m	per t	b-2t / t	A_g	I_x,I_y	Z_x,Z_y	S_x,S_y	r_x,r_y	J	C	k_f	Compactness	Z_e
mm	mm	mm		kg/m	m^2/m	m^2/t		mm^2	10^6 mm^4	10^3 mm^3	10^3 mm^3	mm	10^6 mm^4	10^3 mm^3		C,N,S	10^3 mm^3
300 x	300 x	6.0	SHS	54.7	1.18	21.58	48.0	6963	100	664	764	119.6	154	997	0.70	S	465
		6.3	SHS	57.0	1.17	20.57	45.6	7265	103	689	795	119.3	162	1042	0.74	S	507
		8.0	SHS	71.6	1.17	16.27	35.5	9124	128	853	991	118.4	203	1293	0.95	S	807
		10.0	SHS	88.4	1.16	13.09	28.0	11257	155	1035	1211	117.4	250	1572	1.00	N	1152
		12.0	SHS	103.7	1.14	10.98	23.0	13206	178	1184	1402	116.0	295	1829	1.00	C	1402
		12.5	SHS	107.6	1.14	10.56	22.0	13704	183	1223	1451	115.7	306	1892	1.00	C	1451
		16.0	SHS	134.1	1.12	8.34	16.8	17077	221	1472	1774	113.7	378	2299	1.00	C	1774
350 x	350 x	8.0	SHS	84.2	1.37	16.22	41.8	10724	207	1182	1366	138.9	326	1787	0.80	S	950
		10.0	SHS	104.1	1.36	13.04	33.0	13257	252	1439	1675	137.8	401	2182	1.00	N	1455
		12.0	SHS	122.5	1.34	10.92	27.2	15606	291	1660	1949	136.4	476	2552	1.00	N	1881
		12.5	SHS	127.2	1.34	10.50	26.0	16204	300	1717	2020	136.2	494	2642	1.00	N	1990
		16.0	SHS	159.2	1.32	8.28	19.9	20277	365	2086	2488	134.2	615	3238	1.00	C	2488
400 x	400 x	10.0	SHS	119.8	1.557	13.00	38.0	15257	382	1911	2214	158.3	604	2892	0.88	S	1688
		12.0	SHS	141.3	1.538	10.88	31.3	18006	443	2216	2587	156.9	718	3395	1.00	N	2315
		12.5	SHS	146.8	1.536	10.46	30.0	18704	459	2294	2683	156.6	746	3518	1.00	N	2459
		16.0	SHS	184.3	1.518	8.23	23.0	23477	562	2808	3322	154.7	933	4336	1.00	C	3322

Notes
1. For grade S355; f_y=355 MPa for tube wall thickness t ≤ 16mm or f_y =345 MPa for 16mm < t ≤ 40mm; f_u = 470 Mpa where f_y and f_u are the yield stress and tensile strength respectively used in design to NZS 3404
2. C = compact section; N= non-compact section; S = slender section: as defined in NZS 3404
3. Cold formed hollow sections manufactured to EN 10219 have a residual stress classification of CF in NZS 3404

Rectangular Hollow Sections (RHS)
Dimensions and Properties
EN 10219 Grade S355

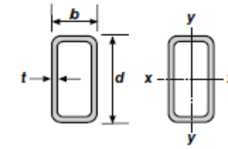


Dimensions and Ratios									Properties											Properties for Design to NZS 3404				
Designation				Mass per m	External Surface Area				Gross Section Area	About x- axis				About y-axis				Torsion constant	Torsion modulus	Form factor	About x- axis		About y-axis	
d	b	t			per m	per t	(b-2t)/t	(d-2t)/t	A_g	Ix	Zx	Sx	rx	Iy	Zy	Sy	ry	J	C	k_f	Compact-ness	Z_e	Compact-ness	Z_e
mm	mm	mm		kg/m	m^2/m	m^2/t			mm^2	10^6 mm^4	10^3 mm^3	10^3 mm^3	mm	10^6 mm^4	10^3 mm^3	10^3 mm^3	mm	10^6 mm^4	10^3 mm^3		C,N,S	10^3 mm^3	C,N,S	10^3 mm^3
300 x	100 x	6.0	RHS	35.8	0.779	21.76	14.67	48.00	4563	47.8	318	411	102.3	8.4	168	188	43.0	24.0	306	0.77	N	335.8	S	118
		6.3	RHS	37.2	0.773	20.75	13.87	45.62	4745	49.1	327	425	101.7	8.7	174	194	42.8	25.2	318	0.80	N	363.9	S	128
		8.0	RHS	46.5	0.766	16.46	10.50	35.50	5924	59.8	399	523	100.5	10.4	209	238	42.0	30.8	385	0.96	C	523.5	S	198
		10.0	RHS	57.0	0.757	13.29	8.00	28.00	7257	71.1	474	631	99.0	12.2	245	285	41.1	36.8	455	1.00	C	630.9	N	272
		12.0	RHS	66.0	0.738	11.19	6.33	23.00	8406	78.1	521	710	96.4	13.4	269	321	40.0	41.8	508	1.00	C	710.3	C	321
		12.5	RHS	68.3	0.736	10.77	6.00	22.00	8704	80.1	534	732	95.9	13.7	275	330	39.7	42.9	521	1.00	C	731.8	C	330
		16.0	RHS	83.8	0.718	8.56	4.25	16.75	10677	91.6	610	865	92.6	15.4	309	386	38.0	49.4	592	1.00	C	865.0	C	386
300 x	150 x	6.0	RHS	40.5	0.879	21.70	23.00	48.00	5163	60.7	405	500	108.5	20.8	277	309	63.5	49.9	479	0.80	N	422.6	S	194
		6.3	RHS	42.2	0.873	20.69	21.81	45.62	5375	62.7	418	517	108.0	21.5	287	321	63.2	52.3	499	0.82	N	455.2	S	211
		8.0	RHS	52.8	0.866	16.40	16.75	35.50	6724	76.8	512	640	106.9	26.2	350	396	62.5	64.9	612	0.96	C	640.3	S	331
		10.0	RHS	64.8	0.857	13.22	13.00	28.00	8257	92.1	614	776	105.6	31.3	417	479	61.5	78.8	733	1.00	C	775.9	N	458
		12.0	RHS	75.4	0.838	11.12	10.50	23.00	9606	103	687	883	103.5	35.0	466	546	60.3	91.5	837	1.00	C	883.1	C	546
		12.5	RHS	78.1	0.836	10.69	10.00	22.00	9954	106	706	912	103.2	35.9	479	563	60.1	94.5	862	1.00	C	911.5	C	563
		16.0	RHS	96.4	0.818	8.48	7.38	16.75	12277	124	826	1092	100.4	41.7	557	673	58.3	113	1015	1.00	C	1092.2	C	673
300 x	200 x	6.0	RHS	45.2	0.979	21.65	31.33	48.00	5763	73.7	491	588	113.1	39.6	396	446	82.9	81.2	651	0.82	N	509.4	S	277
		6.3	RHS	47.1	0.973	20.64	29.75	45.62	6005	76.2	508	610	112.7	41.0	410	463	82.7	85.2	680	0.84	N	546.5	S	302
		8.0	RHS	59.1	0.966	16.35	23.00	35.50	7524	93.9	626	757	111.7	50.4	504	574	81.9	106	838	0.97	C	757.1	S	477
		10.0	RHS	72.7	0.957	13.17	18.00	28.00	9257	113	754	921	110.5	60.6	606	698	80.9	130	1012	1.00	C	920.9	N	667
		12.0	RHS	84.8	0.938	11.06	14.67	23.00	10806	128	853	1056	108.8	68.5	685	801	79.6	152	1167	1.00	C	1055.9	C	801
		12.5	RHS	88.0	0.936	10.64	14.00	22.00	11204	132	879	1091	108.5	70.6	706	828	79.4	158	1204	1.00	C	1091.2	C	828
		16.0	RHS	108.9	0.918	8.42	10.50	16.75	13877	156	1041	1319	106.1	83.4	834	1000	77.5	192	1442	1.00	C	1319.4	C	1000

Notes

1. For grade S355; f_y=355 MPa for tube wall thickness t ≤ 16mm or f_y =345 MPa for 16mm < t ≤ 40mm; f_u = 470 Mpa where f_y and f_u are the yield stress and tensile strength respectively used in design to NZS 3404
2. C = compact section; N= non-compact section; S = slender section: as defined in NZS 3404
3. Cold formed hollow sections manufactured to EN 10219 have a residual stress classification of CF in NZS 3404

Rectangular Hollow Sections (RHS)
Dimensions and Properties
EN 10219 Grade S355



Dimensions and Ratios									Properties											Properties for Design to NZS 3404				
Designation				Mass per m	External Surface Area				Gross Section Area	About x- axis				About y-axis				Torsion constant	Torsion modulus	Form factor	About x- axis		About y-axis	
d	b	t			per m	per t	$\frac{b-2t}{t}$	$\frac{d-2t}{t}$	A_g	Ix	Zx	Sx	rx	Iy	Zy	Sy	ry	J	C	k_f	Compact-ness	Z_e	Compact-ness	Z_e
mm	mm	mm		kg/m	m^2/m	m^2/t			mm^2	$10^6 mm^4$	$10^3 mm^3$	$10^3 mm^3$	mm	$10^6 mm^4$	$10^3 mm^3$	$10^3 mm^3$	mm	$10^6 mm^4$	$10^3 mm^3$		C,N,S	$10^3 mm^3$	C,N,S	$10^3 mm^3$
350 x	250 x	6.0	RHS	54.7	1.179	21.58	39.67	56.33	6963	125	712	843	133.8	74.6	597	671	103.5	146	967	0.70	S	602.4	S	356
		6.3	RHS	57.0	1.173	20.57	37.68	53.56	7265	129	738	876	133.4	77.4	620	698	103.2	153	1010	0.74	S	657.8	S	388
		8.0	RHS	71.6	1.166	16.27	29.25	41.75	9124	160	914	1092	132.4	95.7	766	869	102.4	191	1253	0.89	N	1005.7	S	616
		10.0	RHS	88.4	1.157	13.09	23.00	33.00	11257	194	1109	1335	131.3	116	927	1062	101.5	235	1522	1.00	C	1334.8	N	936
		12.0	RHS	103.7	1.138	10.98	18.83	27.17	13206	222	1268	1544	129.6	133	1061	1229	100.2	277	1770	1.00	C	1543.9	N	1189
		12.5	RHS	107.6	1.136	10.56	18.00	26.00	13704	229	1310	1598	129.3	137	1095	1272	99.9	288	1830	1.00	C	1597.9	N	1255
		16.0	RHS	134.1	1.118	8.34	13.63	19.88	17077	276	1576	1954	127.1	164	1315	1554	98.1	355	2220	1.00	C	1953.6	C	1554
400 x	200 x	8.0	RHS	71.6	1.166	16.27	23.00	48.00	9124	190	949	1173	144.2	65.2	652	728	84.5	158	1133	0.80	N	990.7	S	456
		12.5	RHS	107.6	1.136	10.56	14.00	30.00	13704	271	1355	1714	140.6	92.6	926	1062	82.2	236	1644	1.00	C	1713.9	N	984
		16.0	RHS	134.1	1.118	8.34	10.50	23.00	17077	325	1627	2093	138.1	111	1106	1294	80.5	289	1984	1.00	C	2093.3	C	1294
400 x	300 x	8.0	RHS	84.2	1.366	16.22	35.50	48.00	10724	251	1256	1487	153.1	162	1081	1224	123	312	1747	0.80	S	1187.7	S	756
		10.0	RHS	104.1	1.357	13.04	28.00	38.00	13257	306	1530	1824	152.0	197	1315	1501	122	384	2132	0.93	N	1725.0	S	1162
		12.0	RHS	122.5	1.338	10.92	23.00	31.33	15606	353	1764	2122	150.4	227	1516	1747	121	455	2492	1.00	C	2121.8	N	1578
		12.5	RHS	127.2	1.336	10.50	22.00	30.00	16204	365	1824	2198	150.1	235	1568	1810	120	472	2580	1.00	C	2198.3	N	1671
		16.0	RHS	159.2	1.318	8.28	16.75	23.00	20277	444	2218	2708	147.9	285	1902	2228	119	587	3159	1.00	C	2707.7	C	2228

Notes

1. For grade S355; f_y=355 MPa for tube wall thickness t ≤ 16mm or f_y =345 MPa for 16mm < t ≤ 40mm; f_u = 470 Mpa where f_y and f_u are the yield stress and tensile strength respectively used in design to NZS 3404
2. C = compact section; N= non-compact section; S = slender section: as defined in NZS 3404
3. Cold formed hollow sections manufactured to EN 10219 have a residual stress classification of CF in NZS 3404

Appendix G Material Selection Table

Maximum permissible wall thickness in mm at lowest service temperature of cold-formed hollow sections in service in °C.

Steel grade and subgrade		Charpy-V energy		Lowest temperature [°C] for cold-formed hollow sections Usage $\sigma_{S,d}=0.75 \cdot f_y(t)$							
		°C	J	10	0	-10	-20	-30	-40	-50	-60
EN 10219-2:2006, cold-finished structural **circular** hollow sections of non-alloy and fine-grain steel											
S275	JRH	20	27	35	31	27	23	20	17	15	13
	J0H	0	27	55	43	36	31	26	23	20	17
	J2H	-20	27	75	61	51	43	36	31	26	20
	NH	-20	40	95	73	61	51	43	36	31	26
	NLH	-50	27	135	102	87	73	61	51	43	36
S355	J0H	0	27	42	35	29	25	21	18	15	13
	J2H	-20	27	60	50	42	35	29	25	21	18
	K2H, NH	-20	40	75	60	50	42	35	29	25	21
	NLH	-50	27	110	86	72	60	50	42	35	29
S460	NH	-20	40	60	50	40	33	27	22	19	16
	NLH	-50	27	90	70	58	48	40	33	27	22
EN 10219-2:2006, cold-finished structural **rectangular** hollow sections of non-alloy and fine-grain steel											
S275	JRH	20	27	25	21	18	17	16	14	12	11
	J0H	0	27	33	28	24	21	19	18	16	14
	J2H	-20	27	47	39	33	28	23	21	18	16
	NH	-20	40	56	47	39	33	28	23	21	18
	NLH	-50	27	80	67	56	47	39	33	29	23
S355	J0H	0	27	27	23	21	19	16	14	12	10
	J2H	-20	27	38	32	27	23	19	17	16	14
	K2H, NH	-20	40	46	38	32	27	23	19	17	16
	NLH	-50	27	66	55	46	38	32	27	23	20
S460	NH	-20	40	36	30	24	20	18	17	14	12
	NLH	-50	27	53	44	36	30	24	20	17	14

Notes.

From *Provisions for avoiding brittle fracture in steels used in Australasia* by Hobbacher & Karpenko, 2020.

1. Steels for rectangular hollow sections with welds in or in the vicinity of corners must be resistant against strain ageing.
2. The bending strain at rectangular hollow sections was considered by a temperature shift of ΔT=35°C for t≤16 mm or ΔT=45°C for t>16mm according to European report JRC-ECCS 72702 (Feldmann et. al., 2012).
3. At circular hollow sections the bending strain varies according to *d/t*, so a conservative strain of 10% was assumed for all circular sections resulting in temperature shift of ΔT=20°C, according to European report JRC72702 (Feldmann et al., 2012).

Appendix H Comparison of AS/NZS 1163 and EN 10219

Table H1

Comparison of AS/NZS 1163 and EN 10219 Requirements

Element	AS/NZS 1163	EN 10219
Steel making	• Basic oxygen or electric arc process • Fine-grained, fully killed, continuously cast steels	• Steel making process at discretion of steel maker • Fully killed steels • Non-alloyed or fine-grained steels
Delivery condition	Hot-rolled coil that may be subsequently cold rolled and annealed	• As rolled[1] or, • Normalised/normalised rolled[1] or, • Thermomechanically rolled[1]
Process of manufacture	• Cold-forming process • Electrical resistance welding • Longitudinal seams	• Cold formed without subsequent heat treatment except the weld seam may be in the as-welded or heat-treated condition • Electric resistance welding • Submerged arc without heat treatment • Longitudinal welds or helical if welds tested (radiography to acceptance level U4, butt-weld splice and seam)
Chemistry	CE=C+Mn/6+(Cr+Mo+V)/5+(Ni+Cu)/15 • Grade 250 max. CE 0.25 • Grade 350/450 max. CE 0.43 • No limit on boron	CE=C+Mn/6+(Cr+Mo+V)/5+(Ni+Cu)/15 • Product analysis reported if specific inspection and testing required Non–alloyed steel • S235 max. CE 0.35 • S275 max. CE 0.4 • S355 max. CE 0.45 Fine-grained alloy steels • S275NH/NLH max. CE 0.4 • S275MH/MLH max. CE 0.34 • S355NH/NLH max. CE 0.43 • S355MH/MLH max. CE 0.39 • S420MH/MLH max. CE 0.43 • S460NH/NLH max. CE 0.53 • S460MH/MLH max. CE 0.46 No limit on boron
Grades	• C250, C250L0 • C350, C350L0 • C450, C450L0 L0 (27J @ 0°C)	235, 275, 355, 420, 460 JR (27J @ 20°C) J0 (27J @ 0°C) J2 (27J @ -20°C) K2 (40J @ -20°C)
Test certificates	• Type 3.1[2] • Boron must be reported	• Type 2.2[2] if non-specific inspection[3] specified

	• Test facility accredited for test procedures by ILAC MRA signatory	• Type 3.1[2] if specific inspection[3] specified (Type 3.2[2] if requested by purchaser) • JR, J0 supplied without specific inspection[3]. The purchaser may request specific inspection[3] • J2 and K2 supplied with specific inspection[3] • No requirement to report of boron • No requirement for test facility accreditation for the tests specified in the standard
Identification	• Low-stress die stamp marking • In-line marking • Bundle/pack marking	• Individual product marking (painting, stamping, adhesive label, attached tag) • Or if bundled, the required information may be attached to the bundle
Repair of welds		• Repair of the welds is permissible for alloyed and non-alloyed steels
Repair of surface defects	Yes. By welding or grinding	• Surface defects may be removed by grinding • Non-alloyed steels, repair of the body by welding is permissible unless option 1.5 specified (no repair of the body) • Alloyed steels, no repair of the body unless agreed otherwise
Inspection of welds	• Visual as part of FPC • NDE is at the discretion of manufacturer	• Visual required • If the product is supplied with specific inspection, NDE will be performed on the welds
Inspection of steel surface	Yes	Yes
Mechanical testing	• Tensile test per batch • The tensile test sample is aged by heating to a temperature between 150°C and 200°C for not less than 15 minutes. • Charpy impact (if required) per batch (not required below 6mm thickness, fine-grain structure requirement deemed to comply below 6mm) • Batch definition: Hollow section of the same size, nominal thickness and grade manufactured from the same heat, tube-forming process (tube mill) and rolling (rolling set up)	Non-alloyed steels • Test tensile testing per test unit (only if specific testing required) • JR, J0 impact testing optional Fine-grained steels Specific inspection required for: • Tensile • Impact Test unit definition: A quantity[4] of hollow sections from one or more cast(s) of the same grade and dimensions manufactured by the same process (i.e. electric welding or submerged arc welding) and, if applicable in the same heat treatment

		condition, submitted for acceptance at the same time
Weld tests	Flattening test per batch	
Chemical analysis	Product or cast analysis per heat	Non-alloy steel • One per delivery item (non-specific inspection) • One per cast if specific inspection required Fine-grained steels • One per cast
Conformity	• ITT • FPC	• ITT • FPC (can be third-party certified to annex ZA requirement) • Only mandatory if required for regulatory purposes

Notes.

1. Refer to Appendix B for a discussion of the steel making processes to produce steels to these delivery conditions.
2. Refer to Appendix C for an explanation of the various inspection document types.
3. Refer to Section 1.6 for definitions of non-specific and specific inspection.
4. Refer Table H2 for the mass of a test unit.

Table H2

Test Unit Mass

Type of hollow section		Test unit
Circular	Square or rectangular	
Outside diameter D (mm)	External perimeter (mm)	Mass (tonne)
≤114.3	≤400	40
>114.3≤323.9	>400≤800	50
>323.9	>800	75