Building and Construction Authority

BC1: 2012

Design Guide on Use of Alternative Structural Steel

to BS 5950 and Eurocode 3

BC1: 2012

Design Guide on Use of Alternative Structural Steel to BS 5950 and Eurocode 3

Amendments issued since publication

Amd. No.	Date	Comments
No. 1	1 March 2013	Revision to Section A.2.4, A.3.4, A.3.11, A.5.2, A.5.3, A.5.4
No. 2	1 March 2013	Revision to disclaimer

NOTE

1. *Whilst every effort has been made to ensure accuracy of the information contained in this design guide, the Building and Construction Authority ("BCA") makes no representations or warranty as to the completeness or accuracy thereof. Information in this design guide is supplied on the condition that the user of this publication will make their own determination as to the suitability for his or her purpose(s) prior to its use. The user of this publication must review and modify as necessary the information prior to using or incorporating the information into any project or endeavour. Any risk associated with using or relying on the information contained in the design guide shall be borne by the user. The information in the design guide is provided on an "as is" basis without any warranty of any kind whatsoever or accompanying services or support.*

2. *Nothing contained in this design guide is to be construed as a recommendation or requirement to use any policy, material, product, process, system or application and BCA makes no representation or warranty express or implied. NO REPRESENTATION OR WARRANTY, EITHER EXPRESSED OR IMPLIED OF FITNESS FOR A PARTICULAR PURPOSE IS MADE HEREUNDER WITH RESPECT TO INCLUDING BUT NOT LIMITED, WARRANTIES AS TO ACCURACY, TIMELINES, COMPLETENESS, MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR COMPLIANCE WITH A PARTICULAR DESCRIPTION OR ANY IMPLIED WARRANTY ARISING FROM THE COURSE OF PERFORMANCE, COURSE OF DEALING, USAGE OF TRADE OR OTHERWISE, TO THE FULLEST EXTENT PERMITTED BY LAW. In particular, BCA makes no warranty that the information contained in the design guide will meet the user's requirements or is error-free or that all errors in the drawings can be corrected or that the drawings will be in a form or format required by the user.*

3. *In no event will BCA be responsible or liable for damages of any kind resulting from the use or reliance upon information or the policies, materials, products, systems or applications to which the information refers. In addition to and notwithstanding the foregoing, in no event shall BCA be liable for any consequential or special damages or for any loss of profits incurred by the user or any third party in connection with or arising out of use or reliance of this design guide.*

Contents

List of tables

List of figures

List of symbols

For the purposes of this design guide, the following symbols apply.

f_u Tensile strength of stud shear connector, in N/mm2
L_o Proportional gauge length used to compute elongation in tensile test, in mm
p_{bb} Bearing strength of bolts, in N/mm2
p_s Shear strength of bolts, in N/mm2
p_t Tension strength of bolts, in N/mm2
p_w Design strength of fillet welds, in N/mm2
p_y Design strength of structural steels, in N/mm2
p_{yo} Basic design strength of structural steels with thickness not greater than 16 mm, in N/mm2
S_o Original cross-sectional area of specimen in tensile test, in mm2
t Thickness of steel materials, in mm
U_b Minimum tensile strength of bolts, in N/mm2
U_e Minimum tensile strength of welding consumables, in N/mm2
U_s Minimum tensile strength of structural steels, in N/mm2
Y_b Minimum yield strength of bolts, in N/mm2
Y_s Minimum yield strength of structural steels, in N/mm2; which is taken as the stress at either the initiation of yielding for steel materials with clearly defined yield point; and as the lesser of 0.2% proof stress, or the stress at 0.5% total elongation, for steel materials with no clearly defined yield point

Foreword

This is the 2nd edition of the design guide BC1 which serve as Singapore's national code of practice for the use of alternative structural steel materials in design to the British Standard "BS 5950 Structural Use of Steelwork in Building" and Eurocode 3 "EN 1993 Design of Steel Structures", including those manufactured to British and European Standards. Where applicable, Eurocode 3 refers to the suite of Structural Eurocodes adopted under Singapore Standards SS EN 1993 as well as the Singapore National Annexes to SS EN 1993. Steel materials not covered in BS 5950 and Eurocode 3 by default shall be allowed with or without restrictions if they are in compliance with the provisions of this design guide.

This design guide is expanded to cover additional new steel as well as re-use steel materials previously not considered for applications related to earth retaining or stabilizing structures such as steel strutting system and sheet piles only. The key objective is to ensure that only adequate (in terms of material performance) and reliable (in terms of quality assurance) steel materials, regardless of the standards to which the materials are manufactured to, are used in the design of permanent and temporary structural steelworks to ensure quality and public safety.

This design guide only gives provisions for structural design based on BS 5950 and Eurocode 3, and therefore only serves as guidance at the design stage. It has been assumed in the drafting of this design guide that the execution of its provisions is entrusted to appropriately qualified persons, in compliance with appropriate execution standards to control materials, fabrication and erection of steelwork.

As a code of practice, this design guide takes the form of guidance and recommendations. It should not be quoted as if it was a specification and particular care should be taken to ensure that claims of compliance are not misleading. Reference for additional design recommendations other than those given in this design guide shall be made to relevant parts of BS 5950 and Eurocode 3.

Acknowledgement

The Building and Construction Authority of Singapore (BCA) acknowledges the contribution of A/Prof Chiew Sing-Ping of the School of Civil and Environmental Engineering, Nanyang Technological University for compiling and writing this design guide for BCA.

Section 1. Introduction

1.1 Scope

Under the provisions of this design guide, alternative steel materials not manufactured to British Standards may be allowed in structural design based on BS 5950 and SS EN 1993. To be consistent, this design guide outlines the material performance requirements and quality assurance requirements to be imposed on all steel materials, including those manufactured to British Standards, intended for use in accordance with BS 5950 and SS EN 1993, in the context of Singapore.

1.2 Acronyms

Unless otherwise stated, the following acronyms apply throughout this design guide.

1.2.1 Acronyms for standards and organizations

AS - Australian Standard(s)

AISC - American Institute of Steel Construction

ANSI - American National Standards Institute

API - American Petroleum Institute

ASTM - American Society for Testing and Materials

AWS - American Welding Society

BCA - Building and Construction Authority of Singapore

BS - British Standard(s)

EN - European Standard(s)

GB - National Standard(s) of the People's Republic of China

ISO - International Organization for Standardization

JIS - Japanese Industrial Standard(s)

NZS - New Zealand Standard(s)

SAC - Singapore Accreditation Council

SS - Singapore Standard(s)

1.2.2 Acronyms for technical terms

CEV - Carbon equivalent value

FPC - Factory production control

NDT - Non-destructive testing

1.3 Terms and definitions

For the purposes of this design guide, the following terms and definitions apply.

1.3.1 Alternative steel materials

Alternative steel materials are steel materials not manufactured in accordance with British and European Standards, and therefore not covered in BS 5950 and SS EN 1993 by default. The use of alternative steel materials in BS 5950 and SS EN 1993 shall be allowed with or without recommendations and/or restrictions according to the classification defined in **1.3.2**.

1.3.2 Classification of alternative steel materials

Classification of alternative steel materials is carried out based on the assessments of both material performance requirements defined in **1.3.3** and quality assurance requirements defined in **1.3.4** to categorise alternative steel materials into three classes – Class 1, Class 2 and Class 3 for the purpose of design to BS 5950 and SS EN 1993 defined in **Section 4**.

NOTE See Section 4 for more details on the classification procedure and the description for each class.

1.3.3 Material performance requirements

Material performance requirements are the essential requirements for the mechanical, physical, dimensional and/or other relevant properties of alternative steel materials to ensure their adequacy to be used in the structural design based on BS 5950 and SS EN 1993.

NOTE See Section 2 for more details on structural performance requirements.

1.3.4 Quality assurance requirements

Quality assurance requirements are the requirements for the manufacturers of alternative steel materials to provide adequate assurance on the nominal specifications of the materials, and are acceptable to BCA, to ensure their reliability to be used in the structural design based on BS 5950 and SS EN 1993.

NOTE See Section 3 for more details on quality assurance requirements.

1.3.5 Certified steel materials

Certified steel materials are alternative steel materials which can be found in Singapore and manufactured to one of the five international standards, which are British/European (BS EN), American (API, ASTM and AWS), Japanese (JIS), Australian/New Zealand (AS/NZS and AS) and Chinese (GB) standards, with their nominal specifications already certified to be complying with the essential material performance requirements through rigorous evaluation.

Not all materials manufactured to the abovementioned five international standards are in the lists of certified steel materials (see **Appendix A**), but only those which meet the essential material performance requirements.

NOTE Certified steel materials still need to be classified accordingly (see Section 4).

1.3.6 Manufacturer

The term 'manufacturer' in this design guide shall refer to the manufacturer of steel materials.

1.3.7 Stockist

The term 'stockist' in this design guide shall refer to the supplier of steel materials who does not manufacture the steel materials, but only stocks and supplies the steel materials to the market.

1.3.8 Trader

The term 'trader' in this design guide shall refer to the supplier of steel materials who does not manufacture the steel materials, but only supplies the steel materials to the market.

1.3.9 Purchaser

The term 'purchaser' in this design guide shall refer to the purchaser of steel materials for design, fabrication and erection of steelwork.

1.3.10 Product

The term 'product' in this design guide shall refer to the steel material produced or manufactured by the 'manufacturer' defined in **1.3.6**.

1.3.11 Certification agency

The term 'certification agency' in this design guide shall refer to the independent third-party agency which carries out the duty of auditing the production control system of a manufacturer through necessary inspection, assessment and surveillance.

NOTE Attestation by a certification agency, acceptable to or recognised by BCA, is part of the quality assurance requirements (see Section 3).

1.4 Technical equations

Unless otherwise stated, the following technical equations apply throughout this design guide.

1.4.1 Carbon equivalent value

Carbon equivalent value as a measure of the weldability of steel materials shall be computed using the following equation.

$$CEV\ (\%) = \%C + \frac{\%Mn}{6} + \frac{\%Cr + \%Mo + \%V}{5} + \frac{\%Cu + \%Ni}{15}$$

1.4.2 Proportional gauge length

Proportional gauge length used in computing the elongation as a measure of the ductility of steel materials shall be computed using the following equation.

$$L_o = 5.65\sqrt{S_o}$$

Section 2. Material performance requirements

Alternative steel materials shall be manufactured to a national standard in the first place and they shall, at the same time, meet the relevant material performance requirements. The essential material performance requirements for various types of commonly available alternative steel materials are as given in **2.1**, **2.2**, **2.3**, **2.4**, **2.5**, **2.6**, **2.7**, **2.8**, **2.9**, **2.10** and **2.11**.

Project-specific (internal soundness and through thickness deformation properties, for examples) or other requirements given in BS 5950 or SS EN 1993 but not covered by this design guide (surface and physical conditions, for examples) shall also be complied with.

2.1 Steel plates

This section covers hot-rolled uncoated steel plates with a minimum thickness of 3 mm, supplied flat or pre-curved in any shape as required. Steel for cold forming (see **2.4**) is not within the scope of this section.

NOTE References for material performance requirements in this section include, in alphanumerical order, BS 5950-1, BS 5950-2, BS EN 1993-1-1, BS EN 1993-1-10, BS EN 1993-1-12, BS EN 10025-1, BS EN 10025-2, BS EN 10025-3, BS EN 10025-4, BS EN 10025-5, BS EN 10025-6, BS EN 10029, BS EN 10051 and BS EN 10164.

2.1.1 Manufacturing process

Rimming steel shall not be allowed and the steel shall be at least semi-killed in the deoxidation process.

The plates may be produced directly on reversing mill, by cutting from parent plates rolled on reversing mill or hot rolled wide strips. The plate edges may be as rolled or sheared, flame cut or chamfered.

The products may be supplied in as-rolled, normalized or quenched and tempered condition, or with controlled rolling (normalized rolling or thermo-mechanical rolling).

2.1.2 Mechanical properties

2.1.2.1 *Strength*

The nominal yield strength shall be in the range of 235 N/mm^2 to 690 N/mm^2. The nominal tensile strength shall be in the range of 300 N/mm^2 to 1000 N/mm^2.

2.1.2.2 *Ductility*

The elongation after fracture on proportional gauge length shall be at least 15 %, for nominal yield strength not greater than 460 N/mm^2; and shall be at least 10 % for nominal yield strength greater than 460 N/mm^2. The tensile strength to yield strength ratio shall be at least 1.2 based on nominal values, or at least 1.1 based on actual values, for nominal yield strength not greater than 460 N/mm^2.

NOTE Conversion of elongation values measured not based on proportional gauge length is necessary and shall be performed according to BS EN ISO 2566-1.

2.1.2.3 *Impact toughness*

As a minimum, the product shall be able to absorb at least 27 J of impact energy at 20 °C.

NOTE Depending on other factors including the thickness and minimum service temperature, the impact toughness should also conform to the appropriate requirements as given in BS 5950-1 or BS EN 1993-1-10.

2.1.2.4 *Through thickness deformation properties*

Where appropriate, through thickness deformation properties shall be specified to guarantee adequate deformation capacity perpendicular to the surface to provide ductility and toughness against lamellar tearing.

NOTE Specification of through thickness deformation properties can be referred to BS EN 1993-1-10 and BS EN 10164.

2.1.3 Chemical composition

In general, based on ladle analysis, carbon content shall not exceed 0.26 %; maximum CEV and content of impurities shall be in accordance with the requirements given in Table 1.

NOTE 1 Interpolation for maximum content shall be allowed for design strength not given in Table 1.

NOTE 2 Depending on the product thickness or variation in metallurgical process and intended use, the requirements for chemical composition might vary and shall be referred to BS EN 10025-1, BS EN 10025-2, BS EN 10025-3, BS EN 10025-4, BS EN 10025-5 and BS EN 10025-6.

Table 1 — Chemical composition requirements for steel plates based on ladle analysis

p_y (N/mm^2, based on $t \leq 16$ mm)	Maximum content (% by mass)		
	CEV	P[a]	S
235	0.40	0.045	0.050
275	0.44	0.045	0.050
355	0.49	0.045	0.050
420	0.52	0.040	0.050
460	0.55	0.040	0.050
460[b]	0.50	0.040	0.040
550[b]	0.83	0.030	0.020
690[b]	0.83	0.030	0.020
a For certain weathering steel, maximum phosphorous content shall be allowed up to 0.15 %.			
b For quenched and tempered steel only.			

2.1.4 Dimensional and mass tolerances

2.1.4.1 *Dimensions*

In general, the deviation in actual thickness from nominal plate thickness shall not exceed the smaller of ± 2 mm and ± 15 %.

2.1.4.2 *Mass*

In general, the deviation in actual mass from mass computed using a density of 7850 kg/m^3 shall be limited by the dimensional tolerances.

2.2 Hot rolled sections

This section covers hot rolled structural open sections including universal beams and columns, joists, channels, angles and T sections.

NOTE References for material performance requirements in this section include, in alphanumerical order, BS 5950-1, BS 5950-2, BS EN 1993-1-1, BS EN 1993-1-10, BS EN 10024, BS EN 10025-1, BS EN 10025-2, BS EN 10025-3, BS EN 10025-4, BS EN 10025-5, BS EN 10034, BS EN 10055, BS EN 10056-2, BS EN 10164 and BS EN 10279.

2.2.1 Manufacturing process

Rimming steel shall not be allowed and the steel shall be at least semi-killed in the deoxidation process.

T sections may be produced directly through hot rolling or by splitting the universal beams or columns.

The products may be supplied in as-rolled, normalized or quenched and tempered condition, or with controlled rolling (normalized rolling or thermo-mechanical rolling).

2.2.2 Mechanical properties

2.2.2.1 *Strength*

The nominal yield strength shall be in the range of 235 N/mm^2 to 460 N/mm^2. The nominal tensile strength shall be in the range of 300 N/mm^2 to 750 N/mm^2.

2.2.2.2 *Ductility*

The elongation after fracture on proportional gauge length shall be at least 15 %. The tensile strength to yield strength ratio shall be at least 1.2 based on nominal values, or at least 1.1 based on actual values.

NOTE Conversion of elongation values measured not based on proportional gauge length is necessary and shall be performed according to BS EN ISO 2566-1.

2.2.2.3 *Impact toughness*

As a minimum, the product shall be able to absorb at least 27 J of impact energy at 20 °C.

NOTE Depending on other factors including the thickness and minimum service temperature, the impact toughness should also conform to the appropriate requirements as given in BS 5950-1 or BS EN 1993-1-10.

2.2.3 Chemical composition

In general, based on ladle analysis, carbon content shall not exceed 0.26 %; maximum CEV and content of impurities shall be in accordance with the requirements given in Table 2.

NOTE 1 Interpolation for maximum content shall be allowed for design strength not given in Table 2.

NOTE 2 Depending on the product thickness or variation in metallurgical process and intended use, the requirements for chemical composition might vary and shall be referred to BS EN 10025-1, BS EN 10025-2, BS EN 10025-3, BS EN 10025-4 and BS EN 10025-5.

Table 2 — Chemical composition requirements for hot rolled sections based on ladle analysis

p_y (N/mm^2, based on $t \leq 16$ mm)	Maximum content (% by mass)		
	CEV	P[a]	S
235	0.40	0.045	0.045
275	0.44	0.045	0.045
355	0.49	0.045	0.045
420	0.52	0.040	0.040
460	0.55	0.040	0.040
a For certain weathering steel, maximum phosphorous content shall be allowed up to 0.15 %.			

2.2.4 Dimensional and mass tolerances

2.2.4.1 *Dimensions*

In general, the deviation in the actual overall dimensions like section height, width and leg length shall not exceed the larger of ± 4 mm and ± 3 %; the deviation in the thicknesses of flange, web and leg shall not exceed the smaller of ± 2 mm and ± 15 %.

2.2.4.2 *Mass*

In general, the deviation in actual mass from mass computed using a density of 7850 kg/m^3 shall not exceed ± 6 %, except for T sections where the deviation shall not exceed ± 8 %.

2.3 Hollow sections

This section covers both hot finished and cold-formed structural hollow sections of circular, square or rectangular forms. Hot finished elliptical hollow sections are also within the scope of this section.

NOTE References for material performance requirements in this section include, in alphanumerical order, BS 5950-1, BS 5950-2, BS 7668, BS EN 1993-1-1, BS EN 1993-1-10, BS EN 10210-1, BS EN 10210-2, BS EN 10219-1 and BS EN 10219-2.

2.3.1 Manufacturing process

Rimming steel shall not be allowed and the steel shall be at least semi-killed in the deoxidation process.

Quenched and tempered steel shall not be allowed.

Hollow sections shall be manufactured by a seamless or by a welding process.

Hot finished hollow sections may be formed hot, with or without subsequent heat treatment, or formed cold with subsequent heat treatment to attain the metallurgical conditions equivalent to those formed hot. Hot finished hollow sections may also be supplied in normalized condition or with normalized rolling.

Cold-formed hollow sections shall be formed cold without subsequent heat treatment except the weld seam may be in the as welded or heat treated condition. Cold-formed hollow sections may also be supplied in normalized condition or with controlled rolling (normalized rolling or thermo-mechanical rolling).

2.3.2 Mechanical properties

2.3.2.1 *Strength*

The nominal yield strength shall be in the range of 235 N/mm^2 to 460 N/mm^2. The nominal tensile strength shall be in the range of 300 N/mm^2 to 750 N/mm^2.

2.3.2.2 *Ductility*

The elongation after fracture on proportional gauge length shall be at least 15 %.

NOTE Conversion of elongation values measured not based on proportional gauge length is necessary and shall be performed according to BS EN ISO 2566-1.

2.3.2.3 *Impact toughness*

As a minimum, the product shall be able to absorb at least 27 J of impact energy at 20 °C.

NOTE Depending on other factors including the thickness and minimum service temperature, the impact toughness should also conform to the appropriate requirements as given in BS 5950-1 or BS EN 1993-1-10.

2.3.3 Chemical composition

In general, based on ladle analysis, carbon content shall not exceed 0.24 %; maximum CEV and content of impurities shall be in accordance with the requirements given in Table 3 and Table 4.

NOTE 1 Interpolation for maximum content shall be allowed for design strength not given in Table 3 and Table 4.

NOTE 2 Depending on the product thickness or variation in metallurgical process and intended use, the requirements for chemical composition might vary and shall be referred to BS EN 10210-1 and BS EN 10219-1.

Table 3 — Chemical composition requirements for hot finished hollow sections based on ladle analysis

p_y (N/mm^2, based on $t \leq 16$ mm)	Maximum content (% by mass)		
	CEV	P[a]	S
235	0.41	0.040	0.040
275	0.45	0.040	0.040
355	0.50	0.035	0.035
420	0.52	0.035	0.035
460	0.55	0.035	0.035
a For certain weathering steel, maximum phosphorous content shall be allowed up to 0.15 %.			

Table 4 — Chemical composition requirements for cold-formed hollow sections based on ladle analysis

p_y (N/mm^2, based on $t \leq 16$ mm)	Maximum content (% by mass)		
	CEV	P[a]	S
235	0.37	0.040	0.040
275	0.40	0.040	0.040
355	0.48[b]	0.035	0.035
420	0.50[b]	0.035	0.035
460	0.53[b]	0.035	0.035

a For certain weathering steel, maximum phosphorous content shall be allowed up to 0.15 %.

b If thermo-mechanical rolling, which is recommended to lower the CEV, is introduced, the corresponding maximum CEV allowed shall be reduced by 10 %.

2.3.4 Dimensional and mass tolerances

2.3.4.1 *Dimensions*

In general, the deviation in the actual overall dimensions like section height, width and diameter shall not exceed ± 2 %; the deviation in the wall thicknesses shall not exceed the smaller of ± 2 mm and ± 15 %.

2.3.4.2 *Mass*

In general, the deviation in actual mass from mass computed using a density of 7850 kg/m^3 shall not exceed ± 6 %.

2.4 Steel for cold forming

This section covers steel flat products used for the manufacture of cold-formed open sections such as light-gauge lipped or plain channels and high strength galvanized purlins with a thickness, exclusive of coatings, of not more than 8 mm for use as structural members, and supplied in sheet, strip or coil. Cold-formed structural hollow sections (see **2.3**) and profiled steel sheets for composite slabs (see **2.8**) are not within the scope of this section.

NOTE References for material performance requirements in this section include, in alphanumerical order, BS 5950-5, BS 5950-7, BS EN 1993-1-3, BS EN 10025-2 and BS EN 10051.

2.4.1 Manufacturing process

The steel flat products for cold forming might be hot rolled, cold rolled or continuously hot-dip coated.

For hot rolled steel sheets, strips or coils, rimming steel shall not be allowed and the steel shall be at least semi-killed in the deoxidation process; the products may be supplied in as-rolled, normalized or with controlled rolling (normalized rolling or thermo-mechanical rolling).

For cold rolled steel sheets, strips or coils, low carbon steel shall not be allowed.

For coated steel sheets, strips or coils, low carbon steel shall not be allowed; the coatings might be zinc, zinc-iron alloy, zinc-aluminium alloy, aluminium-zinc alloy or aluminium-silicon alloy.

2.4.2 Mechanical properties

2.4.2.1 *Strength*

The nominal yield strength shall be in the range of 200 N/mm^2 to 550 N/mm^2. The nominal tensile strength shall be in the range of 250 N/mm^2 to 750 N/mm^2.

2.4.2.2 *Ductility*

The elongation after fracture on proportional gauge length shall be at least 15 %, for nominal yield strength not greater than 460 N/mm^2; and shall be at least 10 % for nominal yield strength greater than 460 N/mm^2.

NOTE Conversion of elongation values measured not based on proportional gauge length is necessary and shall be performed according to BS EN ISO 2566-1.

2.4.3 Chemical composition

In general, based on ladle analysis, carbon content shall not exceed 0.25 %, CEV shall not exceed 0.48 % and content of each phosphorous and sulphur shall not exceed 0.05 %. For special steel with high mechanical and/or plastic strain resistances, maximum phosphorous content shall be allowed up to 0.12 %.

NOTE Depending on the product thickness or variation in metallurgical process and intended use, the requirements for chemical composition might vary and shall be referred to BS EN 10025-2, BS EN 10149-2, BS EN 10149-3, BS EN 10268 and BS EN 10346.

2.4.4 Dimensional and mass tolerances

2.4.4.1 *Dimensions*

In general, the deviation in actual thickness from nominal plate thickness shall not exceed the smaller of ± 0.3 mm and ± 15 %.

2.4.4.2 *Mass*

In general, the deviation in actual mass from mass computed using a density of 7850 kg/m^3 shall be limited by the dimensional tolerances.

2.5 Non-preloaded bolting assemblies

This section covers structural bolting assemblies, which include the ISO metric hexagon bolts with the matching nuts and washers, used for non-preloaded or bearing type bolted connections. Bolts with thread size in the range of 5 mm to 68 mm; plain washers with or without chamfer, are covered in this section.

NOTE References for material performance requirements in this section include, in alphanumerical order, BS 4190, BS 4320, BS 5950-1, BS 5950-2, BS EN 1993-1-8, BS EN 20898-2 (ISO 898-2), BS EN ISO 898-1, BS EN ISO 4014, BS EN ISO 4016, BS EN ISO 4017, BS EN ISO 4018, BS EN ISO 4032, BS EN ISO 4033, BS EN ISO 4034 and BS EN ISO 7091.

2.5.1 Manufacturing process

The bolts may be produced by cold forging or hot forging; alloying or quenching and tempering shall be allowed to achieve higher strength; free cutting steel may be allowed for lower grades of bolts.

The nuts may be produced by cold forging, hot forging or by turning from bar; alloying or quenching and tempering shall be allowed to achieve higher strength; free cutting steel may be allowed for lower grades of nuts.

The washers shall be made from mild steel.

2.5.2 Mechanical properties

2.5.2.1 *Strength*

For bolts, the nominal tensile strength shall be in the range of 300 N/mm^2 to 1200 N/mm^2; the recommended grades of non-preloaded bolts, and the corresponding nominal tensile and yield strengths, in accordance with the property class designation system of ISO 898-1 are given in Table 5.

NOTE The nominal strengths given in Table 5 shall not be used as the tension strength for design to BS 5950 (see BS 5950-1).

Table 5 — Recommended grades of non-preloaded bolts

Grade of bolts	Nominal tensile strength (N/mm^2)	Nominal yield strength (N/mm^2)
4.6	400	240
8.8	800	640
10.9	1000	900

For nuts, the proof load stress shall be in the range of 400 N/mm^2 to 1200 N/mm^2; the recommended grades of nuts, and the corresponding proof load stress and the compatible grades of bolts, in accordance with the property class designation system of ISO 898-2 are given in Table 6.

NOTE Nuts of one class higher shall be used when overtapping of nut thread occurs due to the thick coating of bolts.

Table 6 — Recommended grades of nuts in non-preloaded assemblies

Grade of nuts	Proof load stress (N/mm^2)	Compatible bolt grades
4	400	≤ 4.8
8	800	≤ 8.8
10	1000	≤ 10.9

2.5.2.2 *Ductility*

For bolts, the elongation after fracture on proportional gauge length shall be at least 8 %; the reduction in area after fracture shall be at least 35 %.

2.5.2.3 *Hardness*

The bolts and nuts of recommended grades shall be able to meet the one of the three hardness ranges given in Table 7 and Table 8, respectively; whereas the Vickers hardness of the washers shall be in between 100 HV to 200 HV.

Table 7 — Hardness requirements for non-preloaded bolts

Grade of bolts	Range of hardness		
	Vickers hardness (HV)	Brinell hardness (HB)	Rockwell hardness (HRB or HRC)
4.6	120 – 220	114 – 209	67 – 95 (HRB)
8.8	250 – 335	238 – 318	22 – 34 (HRC)
10.9	320 – 380	304 – 361	32 – 39 (HRC)

Table 8 — Hardness requirements for nuts in non-preloaded assembly

Grade of nuts	Range of hardness		
	Vickers hardness (HV)	Brinell hardness (HB)	Rockwell hardness (HRC)
≤ 8	≤ 310	≤ 302	≤ 30
10	≤ 370	≤ 353	≤ 36
12	≤ 395	≤ 375	≤ 39

2.5.3 Chemical composition

For bolts, based on product analysis, carbon content shall not exceed 0.55 %; maximum content of impurities shall be in accordance with the requirements given in Table 9.

Table 9 — Chemical composition requirements for non-preloaded bolts based on product analysis

Grade of bolts	Maximum content (% by mass)	
	P	S
≤ 6.8[a]	0.050	0.060
≥ 8.8	0.050	0.060
a Free cutting steel may be allowed for these grades with the following maximum contents – sulphur 0.34 %, phosphorous 0.11 % and lead 0.35 %.		

For nuts, based on product analysis, maximum content of carbon and impurities shall be in accordance with the requirements given in Table 9.

Table 10 — Chemical composition requirements for nuts in non-preloaded assemblies based on product analysis

Grade of nuts	Maximum content (% by mass)		
	C	P	S
≤ 6[a]	0.50	0.110	0.150
8	0.58	0.060	0.150
10 and 12	0.58	0.048	0.058
a Free cutting steel may be allowed for these grades with the following maximum contents – sulphur 0.34 % and lead 0.35 %.			

2.5.4 Dimensional tolerances

As a minimum, dimensional tolerances shall be in accordance with the corresponding standards which the bolts, nuts and washers are manufactured to.

2.6 Preloaded bolting assemblies

This section covers structural bolting assemblies, which include the ISO metric hexagon bolts with the matching nuts and washers, used for preloaded or non-slip bolted connections. Bolts with thread size in the range of 12 mm to 36 mm; plain washers with or without chamfer and tension indicating washers, are covered in this section.

NOTE References for material performance requirements in this section include, in alphanumerical order, BS 4395-1, BS 4395-2, BS 4604-1, BS 4604-2, BS 5950-1, BS 5950-2, BS 7644-1, BS 7644-2, BS EN 1993-1-8, BS EN 14399-1, BS EN 14399-2, BS EN 14399-3, BS EN 14399-4, BS EN 14399-5, BS EN 14399-6, BS EN 20898-2 (ISO 898-2) and BS EN ISO 898-1.

2.6.1 Manufacturing process

The bolts shall be heat-treated under uniform conditions, and hardened by quenching and tempering.

The nuts shall be heat-treated under uniform conditions, and hardened by quenching and tempering; free cutting steel shall not be allowed.

The washers shall be hardened by quenching and tempering.

2.6.2 Mechanical properties

2.6.2.1 *Strength*

For bolts, the nominal tensile strength shall be in the range of 800 N/mm^2 to 1200 N/mm^2; the recommended grades of preloaded bolts, and the corresponding nominal tensile and yield strengths, in accordance with the property class designation system of ISO 898-1 are given in Table 11.

NOTE The nominal strengths given in Table 5 shall not be used as the tension strength for design to BS 5950 (see BS 5950-1).

Table 11 — Recommended grades of preloaded bolts

Grade of bolts	Nominal tensile strength (N/mm^2)	Nominal yield strength (N/mm^2)
8.8	800	640
10.9	1000	900

For nuts, the proof load stress shall be in the range of 800 N/mm^2 to 1200 N/mm^2; the recommended grades of nuts, and the corresponding proof load stress and the compatible grades of bolts, in accordance with the property class designation system of ISO 898-2 are given in Table 12.

NOTE Nuts of one class higher shall be used when overtapping of nut thread occurs due to the thick coating of bolts.

Table 12 — Recommended grades of nuts in preloaded assemblies

Grade of nuts	Proof load stress (N/mm^2)	Compatible bolt grades
8	800	8.8 or lower
10	1000	10.9 or lower

2.6.2.2 *Ductility*

For bolts, the elongation after fracture on proportional gauge length shall be at least 8 %.

2.6.2.3 *Hardness*

The bolts and nuts of recommended grades shall be able to meet the one of the three hardness ranges given in Table 13 and Table 14, respectively; whereas for the washers, either the Vickers hardness shall be in between 300 HV to 370 HV or the Rockwell hardness shall be in between 38 HRC to 45 HRC.

Table 13 — Hardness requirements for preloaded bolts

Grade of bolts	Range of hardness		
	Vickers hardness (HV)	Brinell hardness (HB)	Rockwell hardness (HRC)
8.8	250 – 335	238 – 318	22 – 34
10.9	320 – 380	304 – 361	32 – 39

Table 14 — Hardness requirements for nuts in preloaded assemblies

Grade of nuts	Range of hardness		
	Vickers hardness (HV)	Brinell hardness (HB)	Rockwell hardness
8	175 – 310	166 – 302	88 HRB – 30 HRC
10	258 – 370	248 – 353	24 HRC – 36 HRC
12	≤ 395	≤ 375	≤ 39 HRC

2.6.3 Chemical composition

For bolts, based on product analysis, carbon content shall not exceed 0.55 %; the maximum content of sulphur and phosphorus shall not exceed 0.06 % each.

For nuts, based on product analysis, maximum content of carbon and impurities shall be in accordance with the requirements given in Table 15.

Table 15 — Chemical composition requirements for nuts in preloaded assemblies based on product analysis

Grade of nuts	Maximum content (% by mass)		
	C	P	S
8	0.58	0.060	0.150
10 and 12	0.58	0.050	0.060

2.6.4 Dimensional tolerances

As a minimum, dimensional tolerances shall be in accordance with the corresponding standards which the bolts, nuts and washers are manufactured to.

2.7 Welding consumables

This section covers welding consumables, including electrodes, wires, rods and fluxes, used in arc welding.

NOTE References for material performance requirements in this section include, in alphanumerical order, BS 5950-1, BS 5950-2, BS EN 1993-1-8, BS EN ISO 636, BS EN ISO 2560, BS EN ISO 14171, BS EN ISO 14341, BS EN ISO 15792-1 and BS EN ISO 17632.

2.7.1 Mechanical properties

The mechanical properties of the all-weld metal shall be obtained through multi run technique.

NOTE Multi run technique shall be referred to BS EN ISO 15792-1 or equivalent.

2.7.1.1 *Strength*

The nominal yield strength of the all-weld metal shall be in the range of 355 N/mm^2 to 690 N/mm^2.

2.7.1.2 *Ductility*

The elongation after fracture of the all-weld metal on proportional gauge length of 5 times the specimen diameter shall be at least 15 %.

NOTE Conversion of elongation values measured not based on proportional gauge length is necessary and shall be performed according to BS EN ISO 2566-1.

2.7.1.3 *Impact toughness*

As a minimum, the all-weld metal shall be able to absorb at least 27 J of impact energy at 20 °C.

NOTE Depending on other factors including the thickness and minimum service temperature, the impact toughness should also conform to the appropriate requirements as given in BS 5950-1 or BS EN 1993-1-10.

2.8 Profiled steel sheets

This section covers profiled steel sheets with a thickness, exclusive of coatings, in the range of 0.7 mm to 5.0 mm for use in composite slabs through composite action.

NOTE References for material performance requirements in this section include, in alphanumerical order, BS 5950-4, BS 5950-6, BS 5950-7, BS EN 1993-1-3, BS EN 10143 and BS EN 10346.

2.8.1 Manufacturing process

The profiled steel sheets shall be continuously hot-dip zinc-coated with structural quality.

2.8.2 Mechanical properties

2.8.2.1 *Strength*

The nominal yield strength shall be in the range of 220 N/mm^2 to 550 N/mm^2. The nominal tensile strength shall be in the range of 275 N/mm^2 to 600 N/mm^2.

2.8.3 Chemical composition

In general, based on ladle analysis, carbon content shall not exceed 0.25 % and content of each phosphorous and sulphur shall not exceed 0.12 % and 0.05 %, respectively.

2.8.4 Dimensional and mass tolerances

2.8.4.1 *Dimensions*

In general, the deviation in actual thickness from nominal plate thickness shall not exceed the smaller of ± 0.2 mm and ± 15 %.

2.8.4.2 *Mass*

In general, the deviation in actual mass from mass computed using a density of 7850 kg/m^3 shall be limited by the dimensional tolerances.

2.9 Stud shear connectors

This section covers headed stud shear connectors used in transmitting the longitudinal shear between concrete and steel in composite beams and slabs. The shank diameter shall be in the range of 10 mm to 25 mm. The head diameter shall be at least 1.5 times the shank diameter; whereas the head depth shall be at least 0.4 times the shank diameter.

NOTE References for material performance requirements in this section include, in alphanumerical order, BS 5950-3.1, BS EN 1994-1-1 and BS EN ISO 13918.

2.9.1 Manufacturing process

The stud shear connectors shall be made from mild steel or stainless steel.

2.9.2 Mechanical properties

2.9.2.1 *Strength*

The nominal tensile strength shall be at least 400 N/mm^2.

2.9.2.2 *Ductility*

The elongation after fracture on proportional gauge length shall be at least 14 %.

NOTE Conversion of elongation values measured not based on proportional gauge length is necessary and shall be performed according to BS EN ISO 2566-1.

2.9.3 Dimensional tolerances

As a minimum, dimensional tolerances shall be in accordance with the corresponding standards which the shear connectors are manufactured to.

2.10 Hot rolled steel bars

This section covers hot rolled flat and square steel bars with overall cross-sectional dimension of not more than 150 mm, as well as round steel bars with diameter of not more than 250 mm.

NOTE References for material performance requirements in this section include, in alphanumerical order, BS 5950-1, BS 5950-2, BS EN 1993-1-1, BS EN 1993-1-10, BS EN 1993-1-12, BS EN 10025-1, BS EN 10025-2, BS EN 10025-3, BS EN 10025-4, BS EN 10025-5, BS EN 10025-6, BS EN 10058, BS EN 10059 and BS EN 10060.

2.10.1 Manufacturing process

Rimming steel shall not be allowed and the steel shall be at least semi-killed in the deoxidation process.

The products may be supplied in as-rolled, normalized or quenched and tempered condition, or with controlled rolling (normalized rolling or thermo-mechanical rolling).

2.10.2 Mechanical properties

2.10.2.1 *Strength*

The nominal yield strength shall be in the range of 235 N/mm^2 to 690 N/mm^2. The nominal tensile strength shall be in the range of 300 N/mm^2 to 1000 N/mm^2.

2.10.2.2 *Ductility*

The elongation after fracture on proportional gauge length shall be at least 15 %, for nominal yield strength not greater than 460 N/mm^2; and shall be at least 10 % for nominal yield strength greater than 460 N/mm^2. The tensile strength to yield strength ratio shall be at least 1.2 based on nominal values, or at least 1.1 based on actual values, for nominal yield strength not greater than 460 N/mm^2.

NOTE Conversion of elongation values measured not based on proportional gauge length is necessary and shall be performed according to BS EN ISO 2566-1.

2.10.2.3 *Impact toughness*

As a minimum, the product shall be able to absorb at least 27 J of impact energy at 20 °C.

NOTE Depending on other factors including the thickness and minimum service temperature, the impact toughness should also conform to the appropriate requirements as given in BS 5950-1 or BS EN 1993-1-10.

2.10.3 Chemical composition

In general, based on ladle analysis, carbon content shall not exceed 0.26 %; maximum CEV and content of impurities shall be in accordance with the requirements given in Table 1.

NOTE 1 Interpolation for maximum content shall be allowed for design strength not given in Table 1.

NOTE 2 Depending on the product thickness or variation in metallurgical process and intended use, the requirements for chemical composition might vary and shall be referred to BS EN 10025-1, BS EN 10025-2, BS EN 10025-3, BS EN 10025-4, BS EN 10025-5 and BS EN 10025-6.

Table 16 — Chemical composition requirements for steel bars based on ladle analysis

p_y (N/mm^2, based on $t \leq 16$ mm)	Maximum content (% by mass)		
	CEV	P[a]	S
235	0.40	0.045	0.050
275	0.44	0.045	0.050
355	0.49	0.045	0.050
420	0.52	0.040	0.050
460	0.55	0.040	0.050
460[b]	0.50	0.040	0.040
550[b]	0.83	0.030	0.020
690[b]	0.83	0.030	0.020

a For certain weathering steel, maximum phosphorous content shall be allowed up to 0.15 %.

b For quenched and tempered steel only.

2.10.4 Dimensional and mass tolerances

2.10.4.1 *Dimensions*

In general, the deviation in actual cross-sectional dimension from nominal dimension shall not exceed the smaller of ± 0.5 mm and ± 10 %.

2.10.4.2 *Mass*

In general, the deviation in actual mass from mass computed using a density of 7850 kg/m^3 shall be limited by the dimensional tolerances.

2.11 Sheet piles

This section covers both hot rolled and cold formed sheet piles, and interlocking steel pipe piles used in earth retaining structures. Steel bearing piles (see **2.2**) and steel pipe piles (see **2.3**), except interlocking steel pipe piles used in earth retaining structures, are not within the scope of this section.

NOTE References for material performance requirements in this section include, in alphanumerical order, BS EN 10025-2, BS EN 10149-2, BS EN 10149-3, BS EN 10051, BS EN 10248-1, BS EN 10248-2, BS EN 10249-1 and BS EN 10249-2.

2.11.1 Manufacturing process

Rimming steel shall not be allowed and the steel shall be at least semi-killed in the deoxidation process.

The products may be supplied in as-rolled, normalized, or with controlled rolling (normalized rolling or thermo-mechanical rolling).

2.11.2 Mechanical properties

2.11.2.1 *Strength*

The nominal yield strength shall be in the range of 235 N/mm^2 to 460 N/mm^2. The nominal tensile strength shall be in the range of 300 N/mm^2 to 750 N/mm^2.

2.11.2.2 *Ductility*

The elongation after fracture on proportional gauge length shall be at least 15 %. The tensile strength to yield strength ratio shall be at least 1.2 based on nominal values, or at least 1.1 based on actual values, for nominal yield strength not greater than 460 N/mm^2.

NOTE Conversion of elongation values measured not based on proportional gauge length is necessary and shall be performed according to BS EN ISO 2566-1.

2.11.3 Chemical composition

In general, based on ladle analysis, carbon content shall not exceed 0.25 %, CEV shall not exceed 0.48 % and content of each phosphorous and sulphur shall not exceed 0.05 %. For special steel with high mechanical and/or plastic strain resistances, maximum phosphorous content shall be allowed up to 0.12 %.

NOTE Depending on the product thickness or variation in metallurgical process and intended use, the requirements for chemical composition might vary and shall be referred to BS EN 10025-2, BS EN 10149-2, BS EN 10149-3, BS EN 10248-1 and BS EN 10249-1.

2.11.4 Dimensional and mass tolerances

2.11.4.1 *Dimensions*

In general, the deviation in actual cross-sectional dimension from nominal dimension shall not exceed ± 0.5 mm for thickness not greater than 5 mm and ± 10 % for thickness greater than 5 mm.

2.11.4.2 *Mass*

In general, the deviation in actual mass from mass computed using a density of 7850 kg/m^3 shall be limited by the dimensional tolerances.

Section 3. Quality assurance requirements

The actual performance and compliance of the steel materials with the nominal specifications stipulated in their respective national standards and material performance requirements from **Section 2** shall be substantiated by a quality assurance system acceptable to BCA.

A manufacturer with an acceptable quality assurance system shall establish a production control system attested with a certificate issued by a certification agency (see **3.1**) and shall provide sufficient guarantee to the purchasers with appropriate test certificates (see **3.2**).

3.1 Factory production control

The manufacturer shall establish, document and maintain a factory production control (FPC) system to ensure the conformity of the products to the nominal specifications.

Such system shall consist of written procedures, regular inspections and tests and/or assessments and the use of the results to control feedstock materials, equipment, personnel, the production process and the products, in accordance with the relevant performance requirements (see **Section 2**).

As a minimum, the production control system shall meet the requirements in **3.1.1**, **3.1.2**, **3.1.3**, **3.1.4**, **3.1.5** and **3.1.6** through attestation by an independent third-party certification agency acceptable to or recognised by BCA on the basis of; first, initial inspection on the system after receiving and analyzing the complete set of manuals of production control system submitted by the manufacturers; second, continuous surveillance and assessment of the production control system through inspection carried out at least once a year.

Certificates of factory production control system, issued by the independent third-party certification agencies acceptable to or recognised by BCA, shall form the acceptable indicator for an attested factory production control system.

3.1.1 Feedstock materials

The source of feedstock and/or raw materials shall be well-documented for a period of at least 7 years to ensure the full traceability of the products.

The specifications of all incoming feedstock and/or raw materials and the relevant inspection scheme to ensure their conformity shall be documented in accordance with the manufacturer's written procedures.

3.1.2 Equipment

All equipment used in the manufacturing process shall be regularly inspected and maintained to ensure consistency in the manufacturing process and the product quality; all weighing, measuring and testing equipment for quality control shall be in accordance with the standards listed in **Appendix B** or the equivalent standards, regularly inspected and calibrated to ensure the reliability and accuracy of results.

Such inspections, maintenances and calibrations shall be carried out and documented in accordance with the manufacturer's written procedures.

3.1.3 Personnel

Qualifications of personnel involved in NDT, process affecting product quality and conformity, based on relevant education, training, skills and experience, shall be assessed and documented in the manufacturer's written procedures.

The responsibilities of personnel managing, performing or verifying work affecting product quality and conformity, and their inter-relationship, shall be clearly defined.

3.1.4 Product testing

The manufacturer shall establish testing procedures to ensure conformity of the products to the nominal specifications. The testing shall be performed in accordance with the standards listed in **Appendix B** or the equivalent standards.

3.1.4.1 *Initial type testing*

Initial type testing shall be carried out under the sole responsibility of the manufacturer before the products are made available in the market and upon the introduction of changes to the manufacturing process which may affect the product characteristics. As a minimum, the initial type testing shall include the experimental and/or theoretical evaluation of the product characteristics corresponding to the relevant performance requirements (see **Section 2**).

3.1.4.2 *Routine testing*

Routine testing shall be carried out by the manufacturer in accordance with the manufacturer's written procedures.

3.1.4.3 *Specific testing*

Specific testing, upon request at the time of order, shall be carried out by authorised inspection representative independent of the manufacturing department prior to delivery to ensure the products to be supplied conform to the nominal specifications and additional requirements made at the time of order.

3.1.5 Product marking

The products shall be properly marked using methods like painting, stamping, laser marking, bar coding, durable adhesive labels or attached tags with the product specifications, particulars of manufacturer and any other essential information. Information corresponding to the relevant material performance requirements given in **Section 2** and **Appendix B** shall be attached in the form of test certificates (see **3.2**).

For bolts to be used for structural purpose, every individual bolt must be properly marked to clearly indicate the grade.

3.1.6 Non-conforming products

The manufacturer shall establish appropriate actions to be taken against products not conforming to the nominal specifications. Occurrence of such non-conformity shall be documented in accordance with the manufacturer's written procedures.

3.2 Manufacturer test certificates

Testing, including inspections, conducted by the manufacturers shall be substantiated by test certificates. As a minimum, a department independent from the production department, within the manufacturer's organization, shall conduct the testing. Upon the request of the purchasers or BCA, certificates issued by an independent third party inspection agency shall also be produced. As a minimum, the manufacturers shall provide quality assurance with manufacturer test certificates containing information given in **3.2.1**, **3.2.2**, **3.2.3**, **3.2.4**, **3.2.5** and **3.2.6**.

3.2.1 Information of manufacturer

The manufacturer's name, contact information and company registration number shall be indicated clearly in the test certificate.

3.2.2 Reference details

The number of purchase order, reference number and date of issue shall be indicated clearly in the test certificate.

3.2.3 Material specifications

The number of material standard and the grade, name or code of material supplied, and/or other useful information about the material supplied, shall be indicated clearly in the test certificate.

3.2.4 Information for traceability

The heat number, batch number of the feedstock materials and the quantity of the steel materials actually supplied to the purchaser shall be indicated clearly in the test certificate.

3.2.5 Test results

The test results, which are corresponding and conforming to the relevant material performance requirements (see **Section 2** and **Appendix B**), shall be indicated clearly in the test certificate. Use of the test results of feedstock materials shall be clearly indicated, if any.

3.2.6 Authentication

The test certificate shall be authenticated with the manufacturer's company stamp, and by the stockist or trader, if appropriate.

Section 4. Classification of steel materials

Classification of steel materials is necessary to determine whether these materials shall be allowed for structural use in the construction industry with or without any restriction. The adequacy and reliability of steel materials shall be verified against the material performance requirements (see **Section 2**) as well as the quality assurance requirements (see **Section 3**), respectively, in the entire process of classification.

This section does not cover the classification of ex-stock steel materials intended for repeated use but delivered without factory production control (FPC) certificate (see **6.1.2**).

4.1 Adequacy assessment

The adequacy of steel materials shall be verified against the material performance requirements. Certification and material testing are the two possible methods to verify the adequacy of steel materials.

4.1.1 Certification

Certification is the process of rigorous evaluation of the specifications given in the British/European, American, Japanese, Australian/New Zealand and Chinese material standards, against the essential material performance requirements. The purpose of certification is to derive lists of certified steel materials as defined in **1.3.5**. Only those materials with their specifications complying with the relevant material performance requirements are included in the lists.

4.1.2 Material testing

Material testing is the process of demonstrating the adequacy of non-certified steel materials not manufactured to British/European, American, Japanese, Australian/New Zealand or Chinese material standards, during the design stage prior to material procurement, through appropriate material sampling and test methods as given in **Appendix B**.

NOTE Material testing for the purpose of adequacy assessment during the design stage shall not exempt the end purchasers from performing the obligatory inspection and testing in accordance with appropriate regulations during procurement and execution.

4.2 Reliability assessment

The reliability of steel materials shall be verified against the quality assurance requirements. Two types of certificates are required to verify the reliability of alternative steel materials. Failure of the manufacturer to produce either one of the certificates given in **4.2.1** or **4.2.2** is considered not meeting the quality assurance requirements.

4.2.1 Factory production control certificates

The manufacturer shall produce a factory production control (FPC) certificate issued by an independent third-party certification agency acceptable to or recognised by BCA as an attestation of the factory production control system in meeting the requirements given in **3.1**.

The purchaser shall obtain a validated copy of such certificate directly from the manufacturer or through the stockist or trader.

4.2.2 Manufacturer test certificates

The manufacturer shall produce an authenticated test certificate (see **3.2**) as an additional layer of quality assurance on the alternative steel materials delivered.

The purchaser shall obtain such certificate directly from the manufacturer or a validated copy of such certificate through the stockist or trader. In both cases, the quantity of steel materials actually supplied to the purchaser shall be clearly indicated.

4.3 Classification procedure

The complete classification procedure of steel materials shall follow the flow represented by the overall framework shown in Figure 1.

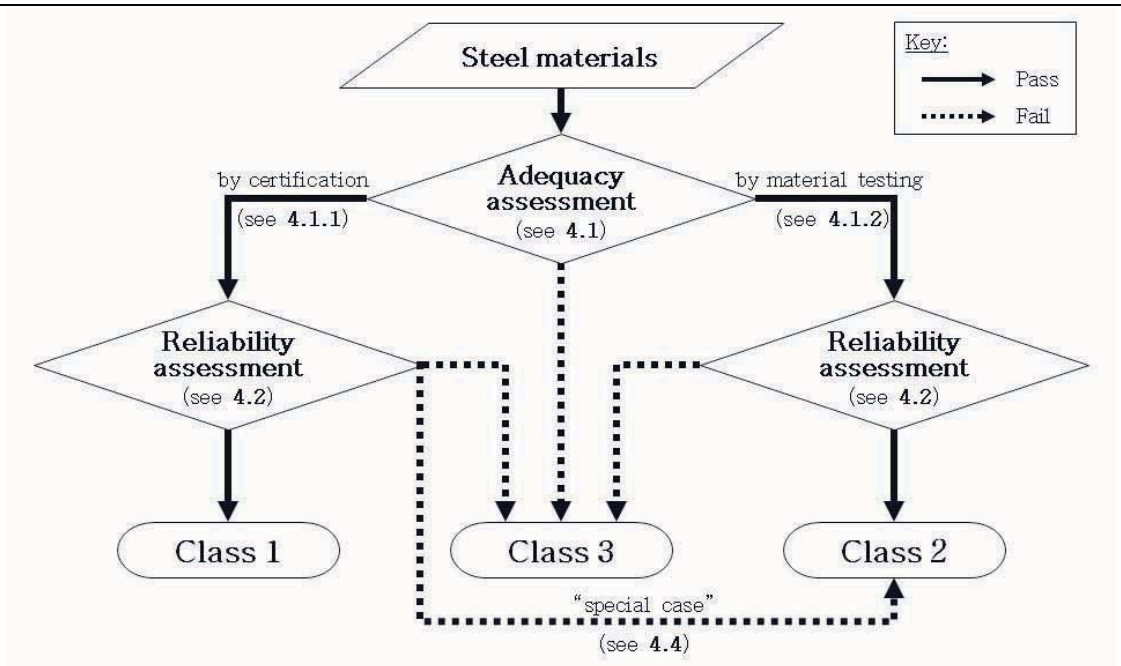


Figure 1 — Overall framework for classification of steel materials

Steel materials shall be classified based on the verification against material performance requirements and quality assurance requirements, see Figure 1, into three classes – Class 1, Class 2 and Class 3, as defined in **4.3.1**, **4.3.2** and **4.3.3**.

4.3.1 Class 1 steel materials

Class 1 steel materials are certified steel materials manufactured with approved quality assurance.

NOTE Only materials in the list of certified materials can be qualified as Class 1 steel materials, depending on the quality assurance provided by the manufacturers.

4.3.2 Class 2 alternative steel materials

Class 2 steel materials are non-certified steel materials which meet the material performance requirements through material testing, and are manufactured with approved quality assurance.

NOTE Materials not in the list of certified materials can only be qualified as Class 2 steel materials, depending on the quality assurance provided by the manufacturers.

4.3.3 Class 3 alternative steel materials

Class 3 steel materials are steel materials which do not meet at least one of the two requirements – material performance requirements and quality assurance requirements.

4.4 Special case

As shown in Figure 1, certified steel materials which fail in reliability assessment may be treated as Class 2 steel materials, on a case-by-case basis subject to approval by BCA, if their reliability can alternatively be guaranteed through rigorous material control and testing plans on site. As a minimum, such written plan should comprise at least 100% visual inspection and non-destructive testing for delivery conditions and dimensional control, at least one set of material testing (in accordance with testing methods given in **Appendix B**) for each batch/lot of steel materials by a SAC accredited laboratory or other laboratory accredited under a mutual recognition agreement with SAC and a material compliance report from an independent expert consultant.

Section 5. Design recommendations

This section covers the design recommendations on the use of three different classes of alternative steel materials, as defined in **4.3.1**, **4.3.2** and **4.3.3**, to BS 5950, SS EN 1993 and SS EN 1994. The major design parameters and equations are given in **5.1**, **5.2** and **5.3** whereas other properties which are common to all three classes of steel materials are given in **5.4**.

5.1 Design recommendations on Class 1 steel materials

This section covers the design guide on Class 1 steel materials, which are in the lists of certified steel materials in **Appendix A** and are in compliance with the quality assurance requirements (see **Section 3**).

5.1.1 Class 1 structural steel

This section covers the design parameters of Class 1 steel plates, hot rolled sections, hollow sections, steel for cold forming, hot rolled steel bars and sheet piles.

The design strength p_y of Class 1 structural steel to BS 5950 shall be computed using the following equation.

Design strength: $$p_y = \frac{Y_s}{1.0} \leq \frac{U_s}{1.2} \text{ or } 460\,\text{N/mm}^2;$$

or $p_y = \frac{Y_s}{1.0} \leq 690\,\text{N/mm}^2$ for steel plates with nominal yield strength of at least 460 N/mm^2, where plastic design shall not be allowed.

The yield strength f_y and ultimate strength f_u of Class 1 structural steel to SS EN 1993 shall be computed using the following equation.

Yield strength: $$f_y = R_{eh};$$

Ultimate strength: $$f_u = 1.2 f_y \quad \text{for } f_y \leq 460\,\text{N/mm}^2;$$

or $f_u = f_y$ for steel plates with nominal yield strength of at least 460 N/mm^2, where plastic design shall not be allowed.

The design parameters p_y and f_y corresponding to different steel grades are given in Table 17, Table 18, Table 19, Table 20 and Table 21.

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

Table 17 — Design parameters of British/European (BS EN) structural steels

Grade	p_y or f_y (N/mm^2), for thickness (mm) less than or equal to					
	16	**40**	**63**	**80**	**100**	**150**
S235	235	225	215	215	215	195
S275	275	265	255	245	235	225
S355	355	345	335	325	315	295
S420	420	400	390	370	360	340
S460	460	440	430	410	400	380
S500	500	500	480	480	480	440
S550	550	550	530	530	530	490
S620	620	620	580	580	580	560
S690	690	690	650	650	650	630

Table 18 — Design parameters of American (ASTM and API) structural steels

Grade	p_y or f_y (N/mm^2), for thickness (mm) less than or equal to				
	32	**50**	**65**	**80**	**100**
ASTM structural steels					
36 [250]	250	240	230	220	210
42 [290]	290	280	270	260	250
50 [345]	345	335	325	315	305
55 [380]	380	370	360	350	340
60 [415]	415	405	395	385	375
65 [450]	450	440	430	420	410
70 [485]	485	475	465	455	445
100 [690]	690	680	670	660	650
API line pipes					
B [L245]	245	235	-	-	-
X42 [L290]	290	280	-	-	-
X46 [L320]	320	310	-	-	-
X52 [L360]	360	350	-	-	-
X56 [L390]	390	380	-	-	-
X60 [L415]	415	405	-	-	-
X65 [L450]	450	440	-	-	-

Table 19 — Design parameters of Japanese (JIS) structural steels

Grade	p_y or f_y (N/mm^2), for thickness (mm) less than or equal to					
	16	**40**	**75**	**100**	**160**	**200**
400	245	235	215	215	205	195
490	325	315	295	295	285	275
490Y	365	355	335	325	-	-
520	365	355	335	325	-	-
570	460	450	430	420	-	-

Table 20 — Design parameters of Australian/New Zealand (AS/NZS) structural steels

Grade	p_y or f_y (N/mm^2), for thickness (mm) less than or equal to					
	12	**20**	**32**	**50**	**80**	**150**
250	250	250	250	250	240	230
300	300	300	280	280	270	260
350	350	350	340	340	340	330
400	400	380	360	360	360	-
450	450	450	420	400	-	-
CA220	210	-	-	-	-	-
CA260	250	-	-	-	-	-
CA350	350	-	-	-	-	-
PT430	300	280	280	270	270	250
PT460	305	295	295	275	275	265
PT490	360	340	340	330	330	320
PT540	450	450	420	400	-	-

Table 21 — Design parameters of Chinese (GB) structural steels

Grade	p_y or f_y (N/mm^2), for thickness (mm) less than or equal to				
	16	**35**	**50**	**100**	**150**
Q235	235	225	215	215	195
Q275	275	265	255	245	225
Q295	295	275	255	235	-
Q345	345	325	295	275	-
Q355	355	345	335	325	-
Q390	390	370	350	330	-
Q420	420	400	380	360	-
Q460	460	440	420	400	-

5.1.2 Class 1 non-preloaded bolted connections

This section covers the design parameters of Class 1 non-preloaded bolts and the recommended combinations of matching components in non-preloaded bolting assemblies.

The design parameters corresponding to different bolt grades are given in Table 22, Table 23, Table 24, Table 25 and Table 26.

Table 22 — Design parameters of British/European (BS EN) non-preloaded bolts

Grade (Bolt marking)	Design strengths to BS 5950			Characteristic values to SS EN 1993	
	Shear strength p_s (N/mm^2)	Bearing strength p_{bb} (N/mm^2)	Tension strength p_t (N/mm^2)	Yield strength f_{yb} (N/mm^2)	Ultimate tensile strength f_{ub} (N/mm^2)
4.6	160	460	240	240	400
8.8	375	1000	560	640	800
10.9	400	1300	700	900	1000

Table 23 — Design parameters of American (ASTM) non-preloaded bolts

Grade (Bolt marking)	Design strengths to BS 5950			Characteristic values to SS EN 1993	
	Shear strength p_s (N/mm^2)	Bearing strength p_{bb} (N/mm^2)	Tension strength p_t (N/mm^2)	Yield strength f_{yb} (N/mm^2)	Ultimate tensile strength f_{ub} (N/mm^2)
307B	160	460	240	240	400
A325	290	640	500	560	725
A449	375	1000	560	640	800
A490	400	1300	700	900	1000

Table 24 — Design parameters of Japanese (JIS) non-preloaded bolts

Grade (Bolt marking)	Design strengths to BS 5950			Characteristic values to SS EN 1993	
	Shear strength p_s (N/mm^2)	Bearing strength p_{bb} (N/mm^2)	Tension strength p_t (N/mm^2)	Yield strength f_{yb} (N/mm^2)	Ultimate tensile strength f_{ub} (N/mm^2)
4.6	160	460	240	240	400
8.8	375	1000	560	640	800
10.9	400	1300	700	900	1000

Table 25 — Design parameters of Australian/New Zealand (AS/NZS) non-preloaded bolts

Grade (Bolt marking)	Design strengths to BS 5950			Characteristic values to SS EN 1993	
	Shear strength p_s (N/mm^2)	Bearing strength p_{bb} (N/mm^2)	Tension strength p_t (N/mm^2)	Yield strength f_{yb} (N/mm^2)	Ultimate tensile strength f_{ub} (N/mm^2)
4.6	160	460	240	240	400
8.8	375	1000	560	640	800
10.9	400	1300	700	900	1000

Table 26 — Design parameters of Chinese (GB) non-preloaded bolts

Grade (Bolt marking)	Design strengths to BS 5950			Characteristic values to SS EN 1993	
	Shear strength p_s (N/mm^2)	Bearing strength p_{bb} (N/mm^2)	Tension strength p_t (N/mm^2)	Yield strength f_{yb} (N/mm^2)	Ultimate tensile strength f_{ub} (N/mm^2)
4.6	125	320	200	190	320
8.8	250	720	400	450	560
10.9	310	930	500	630	700

5.1.3 Class 1 preloaded bolted connections

This section covers the design parameters of Class 1 preloaded bolts and the recommended combinations of matching components in preloaded bolting assemblies.

The design parameters corresponding to different bolt grades are given in Table 27, Table 28, Table 29, Table 30 and Table 31.

Table 27 — Design parameters of British/European (BS EN) preloaded bolts

Grade (Bolt marking)	Design strengths to BS 5950		Characteristic values to SS EN 1993	
	Shear strength p_s (N/mm^2)	Tension strength p_t (N/mm^2)	Yield strength f_{yb} (N/mm^2)	Ultimate tensile strength f_{ub} (N/mm^2)
8.8	375	560	640	800
10.9	400	700	900	1000

Table 28 — Design parameters of American (ASTM) preloaded bolts

Grade (Bolt marking)	Design strengths to BS 5950		Characteristic values to SS EN 1993	
	Shear strength p_s (N/mm^2)	Tension strength p_t (N/mm^2)	Yield strength f_{yb} (N/mm^2)	Ultimate tensile strength f_{ub} (N/mm^2)
A325	290	500	560	725
A354 BC	315	550	680	790
A354 BD	385	675	790	960
A490	400	700	900	1000

Table 29 — Design parameters of Japanese (JIS) preloaded bolts

Grade (Bolt marking)	Design strengths to BS 5950		Characteristic values to SS EN 1993	
	Shear strength p_s (N/mm^2)	Tension strength p_t (N/mm^2)	Yield strength f_{yb} (N/mm^2)	Ultimate tensile strength f_{ub} (N/mm^2)
F8T	375	560	640	800
F10T	400	700	900	1000
F11T	440	770	950	1100
S10T	400	700	900	1000

Table 30 — Design parameters of Australian/New Zealand (AS/NZS) preloaded bolts

Grade (Bolt marking)	Design strengths to BS 5950		Characteristic values to SS EN 1993	
	Shear strength p_s (N/mm^2)	Tension strength p_t (N/mm^2)	Yield strength f_{yb} (N/mm^2)	Ultimate tensile strength f_{ub} (N/mm^2)
8.8	375	560	640	800
10.9	400	700	900	1000
12.9	480	840	1080	1200

Table 31 — Design parameters of Chinese (GB) preloaded bolts

Grade (Bolt marking)	Design strengths to BS 5950		Characteristic values to SS EN 1993	
	Shear strength p_s (N/mm^2)	Tension strength p_t (N/mm^2)	Yield strength f_{yb} (N/mm^2)	Ultimate tensile strength f_{ub} (N/mm^2)
8.8	250	400	450	560
10.9	310	500	630	700

5.1.4 Class 1 fillet welds

This section covers the design recommendations of fillet welds made of Class 1 welding consumables.

The design strengths of fillet welds to BS 5950 corresponding to different welding consumable grades are given in Table 32, Table 33, Table 34, Table 35 and Table 36.

For design to SS EN 1993, the specified strengths, ductility and impact toughness of the welding consumables shall be at least equivalent to that specified for the parent metal.

Table 32 — Design strengths of fillet weld made of British/European (BS EN) welding consumables

Grade	Tensile strength U_e (N/mm^2)	Design strength p_w (N/mm^2)
35	440	$0.50U_e \le 0.55U_s$ U_s = tensile strength of parent metal
38	470	
42	500	
46	530	
50	560	

Table 33 — Design strengths of fillet weld made of American (AWS) welding consumables

Grade	Tensile strength U_e (N/mm^2)	Design strength p_w (N/mm^2)
E49xx	490	245

Table 34 — Design strengths of fillet weld made of Japanese (JIS) welding consumables

Grade	Tensile strength U_e (N/mm^2)	Design strength p_w (N/mm^2)
D43xx	450	225
D50xx	510	255
D53xx	600	300

Table 35 — Design strengths of fillet weld made of Australian/New Zealand (AS/NZS) welding consumables

Grade	Tensile strength U_e (N/mm^2)	Design strength p_w (N/mm^2)
E43xx	430	215
E49xx	490	245
E55xx	550	275
E57xx	570	285

Table 36 — Design strengths of fillet weld made of Chinese (GB) welding consumables

Grade	Tensile strength U_e (N/mm^2)	Design strength p_w (N/mm^2)
43	420	210
50	490	245
55	540	270

5.1.5 Class 1 profiled steel sheets

This section covers the design parameters of Class 1 profiled steel sheets.

The design parameters corresponding to different steel grades are given in Table 37, Table 38, Table 39, Table 40 and Table 41.

Table 37 — Design parameters of British/European (BS EN) profiled steel sheets

Grade	Design strengths p_y to BS 5950				Characteristic values to SS EN 1993	
	Yield strength Y_s (N/mm^2)	Tensile strength U_s (N/mm^2)	BS 5950-4	BS 5950-6	Basic yield strength f_{yb} (N/mm^2)	Ultimate tensile strength f_u (N/mm^2)
S220GD	220	300	0.93Us	$Y_s \le 0.84U_s$	220	300
S250GD	250	330			250	330
S280GD	280	360			280	360
S320GD	320	390			320	390
S350GD	350	420			350	420
S550GD	550	560			550	560

Table 38 — Design parameters of American (ASTM) profiled steel sheets

Grade	Design strengths p_y to BS 5950				Characteristic values to SS EN 1993	
	Yield strength Y_s (N/mm^2)	Tensile strength U_s (N/mm^2)	BS 5950-4	BS 5950-6	Basic yield strength f_{yb} (N/mm^2)	Ultimate tensile strength f_u (N/mm^2)
230	230	310	0.93Us	$Y_s \le 0.84U_s$	230	310
255	255	360			255	360
275	275	380			275	380
340	340	410			340	410
380	380	480			380	480
410	410	480			410	480
480	480	550			480	550
550	550	570			550	570

Table 39 — Design parameters of Japanese (JIS) profiled steel sheets

Grade	Design strengths p_y to BS 5950				Characteristic values to SS EN 1993	
	Yield strength Y_s (N/mm^2)	Tensile strength U_s (N/mm^2)	BS 5950-4	BS 5950-6	Basic yield strength f_{yb} (N/mm^2)	Ultimate tensile strength f_u (N/mm^2)
340	245	340	0.93Us	$Y_s \le 0.84U_s$	245	340
400	295	400			295	400
440	335	440			335	440
490	365	490			365	490
540	400	540			400	540

Table 40 — Design parameters of Australian/New Zealand (AS/NZS) profiled steel sheets

Grade	Design strengths p_y to BS 5950				Characteristic values to SS EN 1993	
	Yield strength Y_s (N/mm^2)	Tensile strength U_s (N/mm^2)	BS 5950-4	BS 5950-6	Basic yield strength f_{yb} (N/mm^2)	Ultimate tensile strength f_u (N/mm^2)
250	250	320	0.93Us	$Y_s \le 0.84U_s$	250	320
300	300	340			300	340
350	350	420			350	420
450	450	480			450	480
500	500	520			500	520
550	550	550			550	550

Table 41 — Design parameters of Chinese (GB) profiled steel sheets

Grade	Design strengths p_y to BS 5950				Characteristic values to SS EN 1993	
	Yield strength Y_s (N/mm^2)	Tensile strength U_s (N/mm^2)	BS 5950-4	BS 5950-6	Basic yield strength f_{yb} (N/mm^2)	Ultimate tensile strength f_u (N/mm^2)
220	220	300	0.93Us	$Y_s \le 0.84U_s$	220	300
250	250	330			250	330
280	280	360			280	360
320	320	390			320	390
350	350	420			350	420
400	400	470			400	470
500	500	530			500	530
550	550	560			550	560

5.1.6 Class 1 stud shear connectors

This section covers the design recommendations of Class 1 stud shear connectors.

The characteristic resistance of stud shear connectors to BS 5950 shall be computed using the following equation.

Characteristic resistance: $$Q_k = 0.29\alpha d^2 \cdot \sqrt{0.8 f_{cu} E_c} \le 0.8 f_u \cdot \frac{\pi d^2}{4}$$

where $\alpha = 0.2\left(\frac{h}{d} + 1\right) \le 1$ for $\frac{h}{d} \ge 3$;

h = overall as-welded height of stud shear connector;

d = shank diameter of stud shear connector;

f_{cu} = cube compressive strength of concrete;

E_c = modulus of elasticity of concrete;

f_u = tensile strength of stud shear connector, but not greater than 450 N/mm^2.

The design shear resistance of stud shear connectors to SS EN 1994 shall be computed using the following equation.

Design shear resistance: $P_{Rd} = \frac{0.8 f_u \pi d^2 / 4}{\gamma_V}$ or $\frac{0.29 \alpha d^2 \sqrt{f_{ck} E_{cm}}}{\gamma_V}$ whichever is smaller,

where α = $0.2\left(\frac{h_{sc}}{d} + 1\right)$ ≤ 1 for $\frac{h_{sc}}{d} \geq 3$;

γ_V = partial factor, the recommended value is 1.25;

h_{sc} = overall nominal height of stud shear connector;

d = shank diameter of stud shear connector, 16 mm $\leq d \leq$ 25 mm;

f_{ck} = cylinder compressive strength of concrete;

E_{cm} = modulus of elasticity of concrete;

f_u = tensile strength of stud shear connector, but not greater than 450 N/mm^2.

The tensile strengths of stud shear connectors manufactured to EN, ASTM, JIS, AS/NZS and GB are given in Table 42.

Table 42 — Tensile strengths of British/European (BS EN), American (AWS), Japanese (JIS), Australian/New Zealand (AS/NZS) and Chinese (GB) stud shear connectors

Material standards	Tensile strength f_u (N/mm^2)
BS EN ISO 13918	450
AWS D1.1 (Type B)	450
JIS B 1198	400
AS/NZS 1554.2	410
GB/T 10433	400

5.2 Design recommendations on Class 2 steel materials

This section covers the design guide on Class 2 steel materials, which are not in the lists of certified steel materials (see **Appendix A**) but are in compliance with both the material performance requirements (see **Section 2**) through material testing and quality assurance requirements (see **Section 3**).

5.2.1 Class 2 structural steel

This section covers the design parameters of Class 2 steel plates, hot rolled sections, hollow sections, steel for cold forming, hot rolled steel bars and sheet piles.

The basic design strength p_{yo} of Class 2 structural steel to BS 5950 corresponding to the thickness not greater than 16 mm shall be computed using the following equation.

Basic design strength: $p_{yo} = \frac{Y_s}{1.1} \leq \frac{U_s}{1.3}$ or 460 N/mm^2

The basic yield strength f_{yo} and ultimate strength f_u of Class 2 structural steel to SS EN 1993 shall be computed using the following equation.

Basic yield strength: $f_{yo} = \frac{R_{eh}}{1.1} \leq \frac{R_m}{1.3}$ or 460 N/mm^2;

Ultimate strength: $f_u = 1.1 f_y$;

where f_y = yield strength corresponding to different thickness as given in Table 43.

The design parameters corresponding to different thickness are given in Table 43.

Table 43 — Design parameters of Class 2 structural steels

Basic design parameters for thickness[a] less than or equal to 16 mm	Design parameters for thickness[a] (mm) less than or equal to				
	40	63	80	100	150
$p_{yo} = \frac{Y_s}{1.1}$ $\leq \frac{U_s}{1.3}$ or 460 N/mm^2	$p_y = 0.95p_{yo}$	$p_y = 0.92p_{yo}$	$p_y = 0.90p_{yo}$	$p_y = 0.85p_{yo}$	$p_y = 0.80p_{yo}$
$f_{yo} = \frac{R_{eh}}{1.1}$ $\leq \frac{R_m}{1.3}$ or 460 N/mm^2	$f_y = 0.95f_{yo}$	$f_y = 0.92f_{yo}$	$f_y = 0.90f_{yo}$	$f_y = 0.85f_{yo}$	$f_y = 0.80f_{yo}$
a For rolled sections, used the specified thickness of the thickest element of the cross-section.					

5.2.2 Class 2 non-preloaded bolted connections

This section covers the design parameters of Class 2 non-preloaded bolts and the recommended combinations of matching components in non-preloaded bolting assemblies.

The design parameters corresponding to different bolt grades are given in Table 44.

Table 44 — Design parameters of Class 2 non-preloaded bolts

Mechanical properties of bolts		Design strengths to BS 5950			Characteristic values to SS EN 1993	
Tensile strength	Yield strength	Shear strength p_s	Bearing strength p_{bb}	Tension strength p_t	Yield strength f_{yb}	Ultimate tensile strength f_{ub}
$U_b \leq 1000$ N/mm^2	Y_b	$0.3U_b$	$0.5(U_b + Y_b)$	$0.5U_b \leq Y_b$	$0.7Y_b$	$0.7U_b$

5.2.3 Class 2 preloaded bolted connections

This section covers the design parameters of Class 2 preloaded bolts and the recommended combinations of matching components in preloaded bolting assemblies.

The design parameters corresponding to different bolt grades are given in Table 45.

Table 45 — Design parameters of Class 2 preloaded bolts

Mechanical properties of bolts		Design strengths to BS 5950		Characteristic values to SS EN 1993	
Tensile strength	Yield strength	Shear strength p_s	Tension strength p_t	Yield strength f_{yb}	Ultimate tensile strength f_{ub}
$U_b \leq 1000$ N/mm^2	Y_b	$0.3U_b$	$0.5U_b \leq Y_b$	$0.7Y_b$	$0.7U_b$

5.2.4 Class 2 fillet welds

This section covers the design strength fillet welds made of Class 2 welding consumables.

The design strength of fillet weld to BS 5950 shall be computed using the following equation.

Design strength of fillet weld: $p_w = 0.4U_e \quad \leq 0.45U_s$

where U_e = tensile strength of all-weld metal, but not greater than 550 N/mm^2

U_s = tensile strength of parent metal

For design to SS EN 1993, the specified strengths of the welding consumables shall be at least equivalent to 1.2 times of that specified for the parent metal, and the specified ductility and impact toughness of the welding consumables shall be at least equivalent to that specified for the parent metal.

5.2.5 Class 2 profiled steel sheets

This section covers the design parameters of Class 2 profiled steel sheets.

The design parameters of profiled steel sheets shall be computed using the following equations.

Design strengths: $p_y = 0.85Y_s$ in design to BS 5950-4

$p_y = 0.9Y_s \leq 0.75U_s$ in design to BS 5950-6

Basic yield strength: $f_{yb} = 0.9Y_s$ in design to SS EN 1993

Ultimate tensile strength: $f_u = 0.9U_s$ in design to SS EN 1993

where Y_s = yield strength of profiled steel sheets, and

U_s = tensile strength of profiled steel sheets, but not greater than 450 N/mm^2

5.2.6 Class 2 stud shear connectors

This section covers the design recommendations of Class 2 stud shear connectors.

The characteristic resistance of stud shear connectors to BS 5950 shall be computed using the following equation.

Characteristic resistance: $Q_k = 0.25\alpha d^2 \cdot \sqrt{0.8 f_{cu} E_c} \quad \leq 0.6 f_u \cdot \frac{\pi d^2}{4}$

where $\alpha = 0.2\left(\frac{h}{d} + 1\right) \leq 1$ for $\frac{h}{d} \geq 3$;

h = overall as-welded height of stud shear connector;

d = shank diameter of stud shear connector;

f_{cu} = cube compressive strength of concrete;

E_c = modulus of elasticity of concrete;

f_u = tensile strength of stud shear connector, but not greater than 450 N/mm^2.

The design shear resistance of stud shear connectors to SS EN 1994 shall be computed using the following equation.

Design shear resistance: $P_{Rd} = \frac{0.6 f_u \pi d^2 / 4}{\gamma_V}$ or $\frac{0.25\alpha d^2 \sqrt{f_{ck} E_{cm}}}{\gamma_V}$ whichever is smaller,

where $\alpha = 0.2\left(\frac{h_{sc}}{d} + 1\right) \leq 1$ for $\frac{h_{sc}}{d} \geq 3$;

γ_V = partial factor, the recommended value is 1.25;

h_{sc} = overall nominal height of stud shear connector;

d = shank diameter of stud shear connector, 16 mm $\leq d \leq$ 25 mm;

f_{ck} = cylinder compressive strength of concrete;

E_{cm} = modulus of elasticity of concrete;

f_u = tensile strength of stud shear connector, but not greater than 450 N/mm^2.

5.3 Design recommendations on Class 3 steel materials

This section covers the design guide on Class 3 steel materials, which are not in compliance with at least one of the material performance requirements (see **Section 2**) or quality assurance requirements (see **Section 3**).

5.3.1 Class 3 structural steel

This section covers the design parameters of Class 3 steel plates, hot rolled sections, hollow sections, steel for cold forming and sheet piles.

The use of Class 3 structural steel is to be restricted to non-structural purpose.

The basic design strength p_{yo} of Class 3 structural steel to BS 5950 corresponding to the thickness not greater than 16 mm shall be taken as 170 N/mm^2.

The basic yield strength f_{yo} Class 3 structural steel to SS EN 1993 corresponding to the thickness not greater than 16 mm shall be taken as 170 N/mm^2 and the ultimate strength f_u shall be computed using the following equation.

Ultimate strength: $f_u = 1.1 f_y$;

where f_y = yield strength corresponding to different thickness as given in Table 46.

The design parameters corresponding to different thickness are given in Table 46.

Table 46 — Design parameters of Class 3 structural steels

p_y or f_y (N/mm^2), for thickness[a] (mm) less than or equal to					
16	**40**	**63**	**80**	**100**	**150**
170	160	155	150	145	135
a For rolled sections, used the specified thickness of the thickest element of the cross-section.					

5.3.2 Class 3 non-preloaded bolted connections

Structural connections shall not be made of Class 3 steel materials.

5.3.3 Class 3 preloaded bolted connections

Structural connections shall not be made of Class 3 steel materials.

5.3.4 Class 3 fillet welds

Structural connections shall not be made of Class 3 steel materials.

5.3.5 Class 3 profiled steel sheets

This section covers the design strength of Class 3 profiled steel sheets.

The nominal yield strength of profiled steel sheets shall be taken as 150 N/mm^2.

5.3.6 Class 3 stud shear connectors

Structural connections shall not be made of Class 3 steel materials.

5.4 Other properties

Unless otherwise stated, the following design values shall be used for steel materials wherever applicable.

— Modulus of elasticity: $E = 205000 \text{N/mm}^2$

— Shear modulus: $G = \frac{E}{2(1+\nu)}$

— Poisson's ratio: $\nu = 0.30$

— Coefficient of linear thermal expansion

(in the ambient temperature range): $\alpha = 12x10^{-6}$ per°C

— Density: $\rho = 7850$ kg/m^3

Section 6. Material traceability and reusability

To promote sustainability in construction industry, steel materials, especially those used in temporary supporting structures, should be reused. This section stipulates the guidelines on the re-use of steel materials through the establishment of material traceability framework and material reusability requirements to ensure both sustainability and safety in re-use of steel materials. This section only covers the re-use of sheet piles and structural steel materials used in steel strutting system for earth retaining or stabilizing structures (ERSS). This section does not cover welding consumables and bolts which shall not be reused after being loosened/removed from existing structural connections.

6.1 Material traceability

Material traceability is the ability to trace back the source of a specific steel material to its original identity as delivered from the mill, through proper identification and quality assurance system.

Suppliers and fabricators who intend to re-use structural steel materials shall establish an in-house quality assurance system to ensure the traceability of such materials. Each piece of steel members shall be marked with a unique identification number of which quality control checks are introduced and recorded. Such unique identification shall be able to facilitate future reference to the factory production control (FPC) certificate, manufacturer test certificate, inspection record and/or test report without confusion.

6.1.1 Traceability of new materials

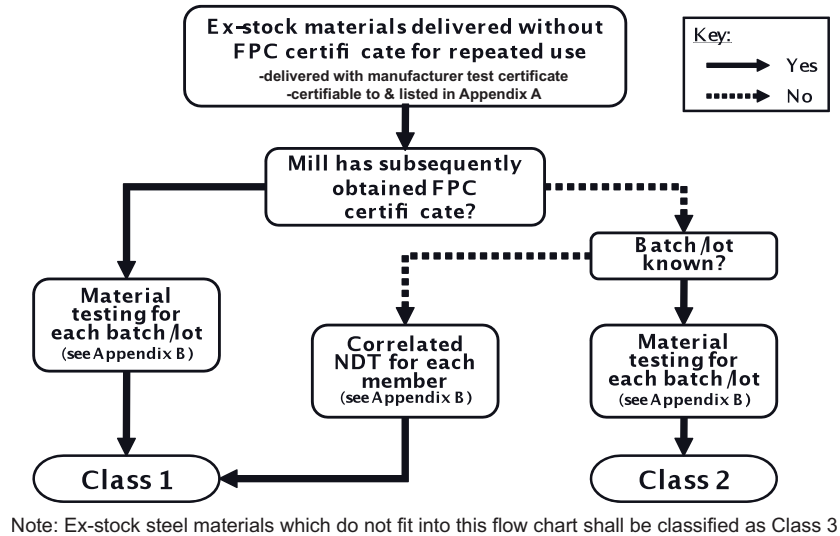
New steel materials intended for repeated use shall be sourced from audited mills with valid factory production control (FPC) certificate (see **4.2.1**) and manufacturer test certificate (see **4.2.2**).

Use of the material for the first time shall be governed by the classification framework given in **Section 4** whereas re-use of the material shall only be permitted upon satisfactory verification against its reusability (see **6.2**).

6.1.2 Traceability of ex-stock materials

Ex-stock steel materials intended for repeated use but delivered without factory production control (FPC) certificate shall be, as a minimum, delivered with manufacturer test certificate (see **4.2.2**) certifiable to and listed in **Appendix A**.

Use of ex-stock steel material shall be classified according to the framework shown in **Figure 2** whereas re-use of the material shall only be permitted upon satisfactory verification against its reusability (see **6.2**).



Note: Ex-stock steel materials which do not fit into this flow chart shall be classified as Class 3

Figure 2 — Classification of ex-stock steel materials for repeated use

6.2 Material reusability

Material reusability is the ability of the used steel materials to be reused and to perform adequately as anticipated in the design.

6.2.1 Recommendations to enhance material reusability

The following recommendations apply to steel materials intended for repeated use.

— Apply permanent and systematic marking for ease of identification;

— Avoid mixing of steel grade for better traceability; and

— Apply corrosion protection coating, if necessary.

6.2.2 Reusability assessment

Steel materials before being reused shall be inspected, and reconditioned if necessary, to ensure compliance with the design requirements. As a minimum, the physical condition and reconditioning requirements given in **6.2.2.1**, **6.2.2.2**, **6.2.2.3**, **6.2.2.4** and **6.2.2.5** shall form the quality test regime to verify the reusability of the materials to be reused. In addition, other requirement(s) can be prescribed by the Qualified Person, if deemed necessary. The flow of reusability of used steel materials is shown in **Figure 3**.

6.2.2.1 *Surface condition*

All surfaces of the steel materials shall be visually inspected. At least 85% of the steel surface shall be free of rust, and the corrosion condition shall not be more severe than Grade C in accordance with BS EN ISO 8501-1.

Should minor repair be required, maintenance actions to be taken include cleaning using water jets, blasting, priming, grinding and weld repair. The area cleaned/ground shall be well flared without abrupt changes in contour.

6.2.2.2 *Sectional dimensions*

Sectional dimensions shall be measured at 3 locations along the members for comparison against the nominal specifications. For open sections, flange thickness shall be measured at 3 quarter points, each at top left half-flange and bottom right half-flange, and web thickness shall be measured at 3 quarter points along beam central axis.

A section intended for re-use shall be relegated to the next lighter section if its actual dimension after blasting/grinding fails to meet the nominal dimension minus allowable tolerance.

6.2.2.3 *Shape and straightness*

Shape and straightness of a used steel member shall comply with the requirements given in BS 5950-2.

Members failing straightness criteria shall be sent for straightening treatment.

6.2.2.4 *Bolts and welded connections*

Structural connections to be re-used shall be visually inspected.

When a used connection is disassembled for purpose like reconditioning the used members and/or modifying the connection, the retrieved bolts shall not be reused again.

6.2.2.5 *Interlocks of sheet piles*

The interlocks of re-used sheet piles shall have adequate free play, so that the piles can be fitted into each other and they shall engage in such a manner that the in-service forces can be transmitted.

6.2.2.6 *Steel materials beyond economic repair*

Used sections which are beyond economic repair/reconditioning shall be scrapped.

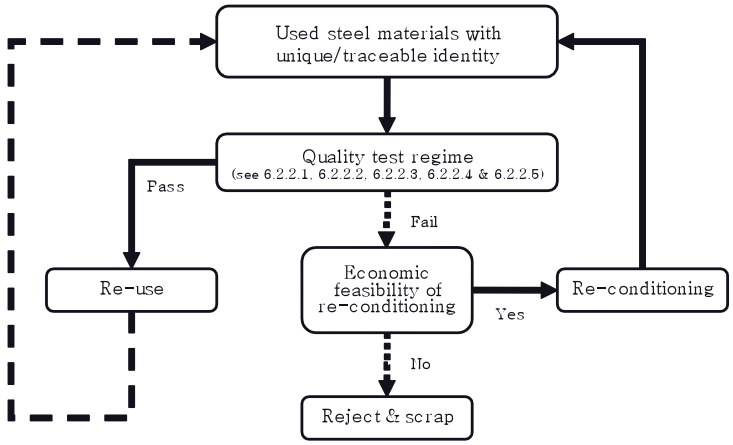


Figure 3 — Assessment of material reusability

6.3 Quality system

To ensure traceability and reusability of steel materials, the supplier/fabricator shall have a proper quality system in place which shall, as a minimum, cover the following.

— Individual marking and identification of reusable steel materials;

— Documentation of FPC certificates, manufacturer test certificates and test reports;

— Record of usage and reconditioning history on the reusable steel materials; and

— In-house inspection and quality test regimes.

Such quality system shall be audited by an independent inspection body acceptable to or recognised by BCA and accredited by the SAC, with subsequent surveillance audits at every 6 months. The inspection body shall issue a certificate of assessment as proof of conformance to the quality system and such certificate shall be made available for inspection by the authorities upon request.

Appendix A Lists of certified steel materials

This appendix only covers certified steel materials manufactured to certain British/European standards (BS EN), American standards (API, ASTM and AWS), Japanese standards (JIS), Australian/New Zealand standards (AS/NZS and AS) and Chinese standards (GB), and shall be updated in accordance with the latest version of the respective standards.

NOTE Depending on the quality assurance provided by the manufacturer, materials in this appendix can be either Class 1 or Class 3.

A.1 Certified British/European steel materials

A.1.1 Certified British/European steel plates

Any combination of steel grades manufactured to:-

BS EN 10025-2:2004
- S235JR
- S235J0
- S235J2
- S275JR
- S275J0
- S275J2
- S355JR
- S355J0
- S355J2
- S355K2

or

BS EN 10025-3:2004
- S275N
- S275NL
- S355N
- S355NL
- S420N
- S420NL
- S460N
- S460NL

or

BS EN 10025-4:2004
- S275M
- S275ML
- S355M
- S355ML
- S420M
- S420ML
- S460M
- S460ML

or

BS EN 10025-5:2004
- S235J0W
- S235J2W
- S355J0WP
- S355J2WP
- S355J0W
- S355J2W
- S355K2W

or

BS EN 10025-6:2009
- S460Q
- S460QL
- S460QL1
- S500Q
- S500QL
- S500QL1
- S550Q
- S550QL
- S550QL1
- S620Q
- S620QL
- S620QL1
- S690Q
- S690QL
- S690QL1

with dimensional and/or mass tolerances in accordance with:-

BS EN 10029:2010
- Class A
- Class B
- Class C
- Class D

or

BS EN 10051:2010
- Category A
- Category B

A.1.2 Certified British/European hot rolled sections

Any combination of steel grades manufactured to:-

BS EN 10025-2:2004
- S235JR
- S235J0
- S235J2
- S275JR
- S275J0
- S275J2
- S355JR
- S355J0
- S355J2
- S355K2

or

BS EN 10025-3:2004
- S275N
- S275NL
- S355N
- S355NL
- S420N
- S420NL
- S460N
- S460NL

or

BS EN 10025-4:2004
- S275M
- S275ML
- S355M
- S355ML
- S420M
- S420ML
- S460M
- S460ML

or

BS EN 10025-5:2004
- S235J0W
- S235J2W
- S355J0WP
- S355J2WP
- S355J0W
- S355J2W
- S355K2W

or

BS EN 10025-6:2009
- S460Q
- S460QL
- S460QL1

with dimensional and/or mass tolerances in accordance with:-

BS EN 10024:1995, BS EN 10034:1993, BS EN 10055:1996, BS EN 10056-2:1993 or BS EN 10279:2000

A.1.3 Certified British/European hollow sections

Either any combination of steel grades manufactured to:-

BS EN 10210-1:2006
- S235JRH
- S275J0H
- S275J2H
- S275NH
- S275NLH
- S355J0H
- S355J2H
- S355K2H
- S355NH
- S355NLH
- S420NH
- S420NLH
- S460NH
- S460NLH

with dimensional and/or mass tolerances in accordance with:-

BS EN 10210-2:2006

Or any combination of steel grades manufactured to:-

BS EN 10219-1:2006
- S235JRH
- S275J0H
- S275J2H
- S275MH
- S275MLH
- S275NH
- S275NLH
- S355J0H
- S355J2H
- S355K2H
- S355MH
- S355MLH
- S355NH
- S355NLH
- S420MH
- S420MLH
- S460MH
- S460MLH
- S460NH
- S460NLH

with dimensional and/or mass tolerances in accordance with:-

BS EN 10219-2:2006

A.1.4 Certified British/European steel for cold forming

Either any combination of steel grades manufactured to:-

BS EN 10025-2:2004
- S235JR
- S235J0
- S235J2
- S275JR
- S275J0
- S275J2
- S355J0
- S355J2
- S355K2

or

BS EN 10149-2:1996
- S315MC
- S355MC
- S420MC
- S460MC
- S500MC
- S550MC

or

BS EN 10149-3:1996
- S260NC
- S315NC
- S355NC
- S420NC

with dimensional and/or mass tolerances in accordance with:-

BS EN 10051:2010

Or any combination of steel grades manufactured to:-

BS EN 10346:2009
- S220GD
- S250GD
- S280GD
- S320GD
- S350GD

with dimensional and/or mass tolerances in accordance with:-

BS EN 10143:2006

A.1.5 Certified British/European non-preloaded bolting assemblies

Bolts manufactured to:-
- BS 4190:2001
- BS 7419:1991
- BS EN ISO 4014:2001
- BS EN ISO 4016:2001
- BS EN ISO 4017:2001
- BS EN ISO 4018:2001

Nuts manufactured to:-
- BS 4190:2001

- BS EN ISO 4032:2001
- BS EN ISO 4033:2001
- BS EN ISO 4034:2001

Washers manufactured to:-
- BS 4320:1968
- BS EN ISO 7091:2000

A.1.6 Certified British/European preloaded bolting assemblies

Bolts manufactured to:-
- BS 4395-1:1969
- BS 4395-2:1969
- BS EN 14399-3:2005
- BS EN 14399-4:2005

Nuts manufactured to:-
- BS 4395-1:1969
- BS 4395-2:1969
- BS EN 14399-3:2005
- BS EN 14399-4:2005

Washers manufactured to:-
- BS 4395-1:1969
- BS 4395-2:1969
- BS EN 14399-5:2005
- BS EN 14399-6:2005

A.1.7 Certified British/European welding consumables

Welding consumables, which result in all-weld metals meeting material performance requirements in **2.7**, and manufactured to:-
- BS EN 760:1996
- BS EN ISO 636:2008
- BS EN ISO 2560:2009
- BS EN ISO 14171:2010
- BS EN ISO 14341:2011
- BS EN ISO 14343:2009
- BS EN ISO 16834:2007
- BS EN ISO 17632:2008
- BS EN ISO 17633:2010
- BS EN ISO 17634:2006
- BS EN ISO 18274:2010
- BS EN ISO 21952:2007
- BS EN ISO 24373:2009
- BS EN ISO 24598:2007
- BS EN ISO 26304:2011

A.1.8 Certified British/European profiled steel sheets

Any combination of steel grades manufactured to:-

BS EN 10346:2009
- S220GD
- S250GD
- S280GD
- S320GD
- S350GD
- S550GD

with dimensional and/or mass tolerances in accordance with:-

BS EN 10143:2006

A.1.9 Certified British/European stud shear connectors

Stud shear connectors manufactured to:-

BS EN ISO 13918:2008

A.1.10 Certified British/European hot rolled steel bars

Any combination of steel grades manufactured to:-

BS EN 10025-2:2004
- S235JR
- S235J0
- S235J2
- S275JR
- S275J0
- S275J2
- S355JR
- S355J0
- S355J2
- S355K2

or

BS EN 10025-3:2004
- S275N
- S275NL
- S355N
- S355NL
- S420N
- S420NL
- S460N
- S460NL

or

BS EN 10025-4:2004
- S275M
- S275ML
- S355M
- S355ML
- S420M
- S420ML
- S460M
- S460ML

or

BS EN 10025-5:2004
- S235J0W
- S235J2W
- S355J0WP
- S355J2WP
- S355J0W
- S355J2W
- S355K2W

or

BS EN 10025-6:2009
- S460Q
- S460QL
- S460QL1
- S500Q
- S500QL
- S500QL1
- S550Q
- S550QL
- S550QL1
- S620Q
- S620QL
- S620QL1
- S690Q
- S690QL
- S690QL1

with dimensional and/or mass tolerances in accordance with:-

BS EN 10058:2003, BS EN 10059:2003 or BS EN 10060:2003

A.1.11 Certified British/European sheet piles

Either any combination of steel grades manufactured to:-

BS EN 10248-1:1996

with dimensional and/or mass tolerances in accordance with:-

BS EN 10248-2:1996

Or any combination of steel grades manufactured to:-

BS EN 10249-1:1996

with dimensional and/or mass tolerances in accordance with:-

BS EN 10249-2:1996

Or any certified steel for cold forming (see **A.1.4**)

A.2 Certified American steel materials

A.2.1 Certified American steel plates

Any combination of steel grades manufactured to:-

ASTM A 36–2008
- Grade 36 [250]

or

ASTM A 242–2004
- Grade 50 [345]

or

ASTM A 572–2007
- Grade 42 [290]
- Grade 50 [345]
- Grade 55 [380]
- Grade 60 [415]
- Grade 65 [450]

or

ASTM A 588–2010
- Grade 50 [345]

or

ASTM A 709–2010
- Grade 36 [250]
- Grade 50 [345]
- Grade 70 [485]
- Grade 100 [690]

or

ASTM A 945–2006
- Grade 50 [345]
- Grade 65 [450]

or

ASTM A 1066–2011
- Grade 50 [345]
- Grade 60 [415]
- Grade 65 [450]
- Grade 70 [485]
- Grade 80 [550]

with dimensional and/or mass tolerances in accordance with:-

ASTM A 6–2010a

A.2.2 Certified American hot rolled sections

Any combination of steel grades manufactured to:-

ASTM A 36–2008
- Grade 36 [250]

or

ASTM A 572–2007
- Grade 42 [290]
- Grade 50 [345]
- Grade 55 [380]
- Grade 60 [415]
- Grade 65 [450]

or

ASTM A 588–2010
- Grade 50 [345]

or

ASTM A 709–2010
- Grade 36 [250]
- Grade 50 [345]

or

ASTM A 913–2011
- Grade 50 [345]
- Grade 60 [415]
- Grade 65 [450]

or

ASTM A 992–2011
- Grade 50 [345]

with dimensional and/or mass tolerances in accordance with:-

ASTM A 6–2010a

A.2.3 Certified American hollow sections

Steel grades manufactured to:-

ASTM A 501-2007
- Grade 50 [345]

or

API 5L–2010
- Grade B [L245]
- Grade X42 [L290]
- Grade X46 [L320]
- Grade X52 [L360]
- Grade X56 [L390]
- Grade X60 [L415]
- Grade X65 [L450]

A.2.4 Certified American steel for cold forming

Any combination of steel grades manufactured to:-

ASTM A 792–2010
- SS Grade 33 [230]
- SS Grade 37 [255]
- SS Grade 40 [275]
- SS Grade 50 [340]
- SS Grade 60 [410]
- SS Grade 70 [480]
- SS Grade 80 [550]

or

ASTM A 875–2010
- SS Grade 33 [230]
- SS Grade 37 [255]
- SS Grade 50 [340]
- SS Grade 80 [550]

or

ASTM A 1008–2010
- SS Grade 30 [205]
- SS Grade 33 [230]
- SS Grade 40 [275]
- SS Grade 45 [310]
- SS Grade 50 [340]
- SS Grade 60 [410]
- SS Grade 70 [480]
- SS Grade 80 [550]

or

ASTM A 1011–2010
- SS Grade 30 [205]
- SS Grade 33 [230]
- SS Grade 36 [250]
- SS Grade 40 [275]
- SS Grade 45 [310]
- SS Grade 50 [340]
- SS Grade 55 [380]
- SS Grade 60 [410]
- SS Grade 70 [480]
- SS Grade 80 [550]

with dimensional and/or mass tolerances in accordance with:-

ASTM A 568–2009a or ASTM A 924–2010a

A.2.5 Certified American non-preloaded bolting assemblies

Bolts manufactured to:-
- ASTM A 193–2010a
- ASTM A 307–2010 (Grade B)
- ASTM A 325–2009
- ASTM A 449–2010
- ASTM A 490–2010

Nuts manufactured to:-
- ASTM A 563–2007
- ASTM A 194–2010a

Washers manufactured to:-
- ASTM F 436–2010

A.2.6 Certified American preloaded bolting assemblies

Bolts manufactured to:-
- ASTM A 325–2009
- ASTM A 354–2007a (Grade BC and Grade BD)
- ASTM A 490–2010

Nuts manufactured to:-
- ASTM F 1852–2008
- ASTM A 563–2007

Washers manufactured to:-
- ASTM F 959–2007
- ASTM F 436–2010

A.2.7 Certified American welding consumables

Welding consumables, which result in all-weld metals meeting material performance requirements in **2.7**, and manufactured to:-

- AWS A5.1:2004
- AWS A5.9:2005

A.2.8 Certified American profiled steel sheets

Any combination of steel grades manufactured to:-

ASTM A 653–2010
- Grade 33 [230]
- Grade 37 [255]
- Grade 40 [275]
- Grade 50 [340]
- Grade 55 [380]
- Grade 60 [410]
- Grade 70 [480]
- Grade 80 [550]

or

ASTM A 1046-2010a
- Grade 33 [230]
- Grade 37 [255]
- Grade 40 [275]
- Grade 50 [340]
- Grade 80 [550]

with dimensional and/or mass tolerances in accordance with:-

ASTM A 924–2010a

A.2.9 Certified American shear stud connectors

Stud shear connectors manufactured to:-

AWS D1.1–2010
- Type B

A.2.10 Certified American hot rolled steel bars

Any combination of steel grades manufactured to:-

ASTM A 709–2010

with dimensional and/or mass tolerances in accordance with:-

ASTM A 6–2010a

A.2.11 Certified American sheet piles

Either any combination of steel grades manufactured to:-

- ASTM A 328–2007
- ASTM A 857–2007

with dimensional and/or mass tolerances in accordance with:-

ASTM A 6–2010a

Or any certified steel for cold forming (see **A.2.4**)

A.3 Certified Japanese steel materials

A.3.1 Certified Japanese steel plates

Any combination of steel grades manufactured to:-

JIS G 3106:2008
- SM400B
- SM400C
- SM490B
- SM490C
- SM490YB
- SM520B
- SM520C

- SM570

or

JIS G 3114:2008
- SMA400BP
- SMA400BW
- SMA400CP
- SMA400CW

- SMA490BP
- SMA490BW
- SMA490CP
- SMA490CW
- SMA570P
- SMA570W

or

JIS G 3136:2005
- SN400B
- SN400C
- SN490B
- SN490C

with dimensional and/or mass tolerances in accordance with:-

JIS G 3193:2008

A.3.2 Certified Japanese hot rolled sections

Any combination of steel grades manufactured to:-

JIS G 3106:2008
- SM400B
- SM400C
- SM490B
- SM490C
- SM490YB
- SM520B
- SM520C

- SM570

or

JIS G 3114:2008
- SMA400BP
- SMA400BW
- SMA400CP
- SMA400CW

- SMA490BP
- SMA490BW
- SMA490CP
- SMA490CW
- SMA570P
- SMA570W

or

JIS G 3136:2005
- SN400B
- SN400C
- SN490B
- SN490C

with dimensional and/or mass tolerances in accordance with:-

JIS G 3192:2010

A.3.3 Certified Japanese hollow sections

Steel grades manufactured to:-

JIS G 3475:2008
- STKN400B
- STKN400W
- STKN490B

A.3.4 Certified Japanese steel for cold forming

Either any combination of steel grades manufactured to:-

JIS G 3106:2008
- SM400B
- SM400C
- SM490B
- SM490C
- SM490YB
- SM520B
- SM520C

- SM570

or

JIS G 3114:2008
- SMA400BP
- SMA400BW
- SMA400CP
- SMA400CW

- SMA490BP
- SMA490BW
- SMA490CP
- SMA490CW
- SMA570P
- SMA570W

or

JIS G 3136:2005
- SN400B
- SN400C
- SN490B
- SN490C

with dimensional and/or mass tolerances in accordance with:-

JIS G 3193:2008

Or steel grade manufactured to:-

JIS G 3350:2009
- SSC400

A.3.5 Certified Japanese non-preloaded bolting assemblies

Bolts manufactured to:-
- JIS B 1051:2000
- JIS B 1180:2009

Nuts manufactured to:-
- JIS B 1052-2:2009
- JIS B 1052-6:2009
- JIS B 1181:2009

Washers manufactured to:-
- JIS B 1256:2008

A.3.6 Certified Japanese preloaded bolting assemblies

Bolts manufactured to:-
- JIS B 1186:2007
- JSS II-09:1981

Nuts manufactured to:-
- JIS B 1186:2007

Washers manufactured to:-
- JIS B 1186:2007

A.3.7 Certified Japanese welding consumables

Welding consumables, which result in all-weld metals meeting material performance requirements in **2.7**, and manufactured to:-
- JIS Z 3211:2008
- JIS Z 3313:2009

A.3.8 Certified Japanese profiled steel sheets

Steel grades manufactured to:-

JIS G 3302:2010
- SGH340
- SGH400
- SGH440
- SGH490
- SGH540
- SGC340
- SGC400
- SGC440
- SGC490

or

JIS G 3317:2010
- SZAH340
- SZAH400
- SZAH440
- SZAH490
- SZAH540
- SZAC340
- SZAC400
- SZAC440
- SZAC490

or

JIS G 3321:2010
- SGLH400
- SGLH440
- SGLH490
- SGLH540
- SGL400
- SGL440
- SGL490

A.3.9 Certified Japanese stud shear connectors

Stud shear connectors manufactured to:-

JIS B 1198:2011

A.3.10 Certified Japanese hot rolled steel bars

Any combination of steel grades manufactured to:-

JIS G 3106:2008
- SM400B
- SM400C
- SM490B
- SM490C
- SM490YB
- SM520B
- SM520C
- SM570

or

JIS G 3114:2008
- SMA400BP
- SMA400BW
- SMA400CP
- SMA400CW
- SMA490BP
- SMA490BW
- SMA490CP
- SMA490CW
- SMA570P
- SMA570W

or

JIS G 3136:2005
- SN400B
- SN400C
- SN490B
- SN490C

with dimensional and/or mass tolerances in accordance with:-

JIS G 3191:2010

A.3.11 Certified Japanese sheet piles

Either steel grades manufactured to:-

- JIS A 5523:2006
- JIS A 5530:2010

Or any combination of steel grades manufactured to standards listed under:-

- **A.1.8**
- **A.2.8**
- **A.4.8**
- **A.5.8**

with dimensional and/or mass tolerances in accordance with:-

JIS A 5528:2006

Or any certified steel for cold forming (see **A.3.4**)

A.4 Certified Australian/New Zealand steel materials

A.4.1 Certified Australian/New Zealand steel plates

Either any combination of steel grades manufactured to:-

AS/NZS 3678-2011
- 250
- 300
- 350
- 400
- 450

with dimensional and/or mass tolerances in accordance with:-

AS/NZS 1365-1996*

NOTE *Plates are rolled on continuous mills. If plates are rolled on reversing mills, width of plate should be less than 2.7 m.

Or steel grades manufactured to:-

AS 1548-2008
- PT430NL0
- PT430NL20
- PT430NL40
- PT430NRL0
- PT430NRL20
- PT430NRL40
- PT430TRL0
- PT430TRL20
- PT430TRL40
- PT460NL0
- PT460NL20
- PT460NL40
- PT460NL50
- PT460NRL0
- PT460NRL20
- PT460NRL40
- PT460NRL50
- PT460TRL0
- PT460TRL20
- PT460TRL40
- PT460TRL50
- PT490N
- PT490NL20
- PT490NL40
- PT490NL50
- PT490NR
- PT490NRL20
- PT490NRL40
- PT490NRL50
- PT490T
- PT490TL20
- PT490TL40
- PT490TL50
- PT540T
- PT540TL20
- PT540TL40
- PT540TL50

A.4.2 Certified Australian/New Zealand hot rolled sections

Hot rolled sections manufactured to:-

AS/NZS 3679.1-2010
- 300L0
- 300L15
- 300S0
- 350L0
- 350S0

A.4.3 Certified Australian/New Zealand hollow sections

Steel grades manufactured to:-

AS/NZS 1163-2009
- C250L0
- C350L0
- C450L0

A.4.4 Certified Australian/New Zealand steel for cold forming

Any combination of steel grades manufactured to:-

AS/NZS 1397-2001
- 250
- 300
- 350
- 400
- 450

with dimensional and/or mass tolerances in accordance with:-

AS/NZS 1365-1996

Or any combination of steel grades manufactured to:-

AS/NZS 1595-1998
- CA220
- CA260
- CA350

with dimensional and/or mass tolerances in accordance with:-

AS/NZS 1365-1996

A.4.5 Certified Australian/New Zealand non-preloaded bolting assemblies

Bolts manufactured to:-
- AS/NZS 1252-1996
- AS 4291.1-2000*
- AS/NZS 1559-1997

NOTE *Grade 12.9 is non-certified.

Nuts manufactured to:-
- AS/NZS 1252-1996
- AS/NZS 4291.2-1995

Washers manufactured to:-
- AS/NZS 1252-1996

A.4.6 Certified Australian/New Zealand preloaded bolting assemblies

Bolts manufactured to:-
- AS/NZS 1252-1996
- AS 4291.1-2000

Nuts manufactured to:-
- AS/NZS 1252-1996
- AS/NZS 4291.2:1995

Washers manufactured to:-
- AS/NZS 1252-1996

A.4.7 Certified Australian/New Zealand welding consumables

Welding consumables, which result in all-weld metals meeting material performance requirements in **2.7**, and manufactured to:-
- AS/NZS 1554.1-2004
- AS/NZS 4855-2007
- AS/NZS 4857-2006*
- AS 1858.1-2003**
- AS/NZS 2717.1-1996

NOTE *Only grades 55, 62 and 69 are certified.

NOTE **Z is non-certified.

NOTE ***Only grades W5xxx to W6xxx are certified; grade W5ZXH is non-certified.

A.4.8 Certified Australian/New Zealand profiled steel sheets

Any combination of steel grades manufactured to:-

AS/NZS 1397-2001
- 250
- 300
- 350
- 400
- 450
- 500
- 550

with dimensional and/or mass tolerances in accordance with:-

AS/NZS 1365-1996

A.4.9 Certified Australian/New Zealand shear stud connectors

Stud shear connectors manufactured to:-

AS/NZS 1554.2-2003*

NOTE *Stud diameter should be at least 15.9 mm.

A.4.10 Certified Australian/New Zealand hot rolled steel bars

Hot rolled steel bars manufactured to:-

AS/NZS 3679.1-2010

A.4.11 Certified Australian/New Zealand sheet piles

Any certified steel for cold forming (see **A.4.4**)

A.5 Certified Chinese steel materials

A.5.1 Certified Chinese steel plates

Any combination of steel grades manufactured to:-

GB/T 700-2006*
- Q235BZ
- Q235CZ
- Q235DTZ
- Q275BZ
- Q275CZ
- Q275DTZ

or

GB/T 1591-2008*
- Q345B
- Q345C
- Q345D
- Q345E
- Q390B
- Q390C
- Q390D
- Q390E
- Q420B
- Q420C
- Q420D
- Q420E
- Q460C
- Q460D
- Q460E
- Q500C
- Q500D
- Q500E
- Q550C
- Q550D
- Q550E
- Q620C
- Q620D
- Q620E
- Q690C
- Q690D
- Q690E

or

GB/T 4171-2008
- Q265GNH
- Q295GNH
- Q310GNH
- Q355GNH
- Q235NH
- Q295NH
- Q355NH
- Q415NH
- Q460NH
- Q500NH
- Q550NH

or

GB/T 19879-2005
- Q235GJC
- Q235GJD
- Q235GJE
- Q345GJC
- Q345GJD
- Q345GJE
- Q390GJC
- Q390GJD
- Q390GJE
- Q420GJC
- Q420GJD
- Q420GJE
- Q460GJC
- Q460GJD
- Q460GJE

with dimensional and/or mass tolerances in accordance with:-

GB/T 709-2006*
- Class A
- Class B
- Class C
- Class N
- PT.A
- PT.B

NOTE *Steel plates manufactured to GB 912-2008 and GB/T 3274-2007, which make reference to GB/T 700-2006, GB/T 1591-2008 and GB/T 709-2006, shall be considered certified.

A.5.2 Certified Chinese hot rolled sections

Any combination of steel grades manufactured to:-

GB/T 700-2006
- Q235BZ
- Q235CZ
- Q235DTZ
- Q275BZ
- Q275CZ
- Q275DTZ

or

GB/T 1591-2008
- Q295B
- Q345B
- Q345C
- Q345D
- Q345E
- Q390B
- Q390C
- Q390D
- Q390E
- Q420B
- Q420C
- Q420D
- Q420E
- Q460C
- Q460D
- Q460E

or

GB/T 4171-2008
- Q265GNH
- Q295GNH
- Q310GNH
- Q355GNH
- Q235NH
- Q295NH
- Q355NH
- Q415NH
- Q460NH

with dimensional and/or mass tolerances in accordance with:-

GB/T 706-2008 or GB/T 11263-2010

A.5.3 Certified Chinese hollow sections

Either any combination of steel grades manufactured to:-

GB/T 700-2006
- Q235CZ
- Q235DTZ
- Q275CZ
- Q275DTZ

or

GB/T 1591-2008
- Q345C
- Q345D
- Q345E
- Q390C
- Q390D
- Q390E
- Q420C
- Q420D
- Q420E
- Q460C
- Q460D
- Q460E

or

GB/T 4171-2008
- Q265GNH
- Q295GNH
- Q310GNH
- Q355GNH
- Q235NH
- Q295NH
- Q355NH
- Q415NH
- Q460NH

with dimensional and/or mass tolerances in accordance with:-

GB/T 6728-2002

Or any combination of steel grades manufactured to:-

GB/T 8162-2008
- Q235B
- Q235C
- Q235D
- Q275B
- Q275C
- Q275D
- Q295B
- Q345B
- Q345C
- Q345D
- Q345E
- Q390B
- Q390C
- Q390D
- Q390E
- Q420B
- Q420C
- Q420D
- Q420E
- Q460C
- Q460D
- Q460E

with dimensional and/or mass tolerances in accordance with:-

GB/T 8162-2008 and GB/T 17395-2008

A.5.4 Certified Chinese steel for cold forming

Any combination of steel grades manufactured to:-

GB/T 700-2006
- Q215AZ
- Q215BZ
- Q235AZ
- Q235BZ
- Q235CZ
- Q235DTZ
- Q275AZ
- Q275BZ
- Q275CZ
- Q275DTZ

or

GB/T 1591-2008
- Q345A
- Q345B
- Q345C
- Q345D
- Q345E
- Q390A
- Q390B
- Q390C
- Q390D
- Q390E
- Q420A
- Q420B
- Q420C
- Q420D
- Q420E

with dimensional and/or mass tolerances in accordance with:-

GB/T 709-2006

A.5.5 Certified Chinese non-preloaded bolting assemblies

Bolts manufactured to:-
- GB/T 5780-2000
- GB/T 5781-2000
- GB/T 5782-2000
- GB/T 5783-2000

Nuts manufactured to:-
- GB/T 41-2000
- GB/T 6170-2000
- GB/T 6175-2000

Washers manufactured to:-
- GB/T 95-2002

A.5.6 Certified Chinese preloaded bolting assemblies

Bolts manufactured to:-
- GB/T 1228-2006
- GB/T 3632-2008

Nuts manufactured to:-
- GB/T 1229-2006
- GB/T 3632-2008

Washers manufactured to:-
- GB/T 1230-2006
- GB/T 3632-2008

A.5.7 Certified Chinese welding consumables

Welding consumables, which result in all-weld metals meeting material performance requirements in **2.7**, and manufactured to:-
- GB/T 5117-1995
- GB/T 5118-1995
- GB/T 5293-1999
- GB/T 8110-2008
- GB/T 10045-2001
- GB/T 12470-2003
- GB/T 17493-2008

A.5.8 Certified Chinese profiled steel sheets

Profiled steel sheets manufactured to:-

GB/T 2518-2008
- S220GD
- S250GD
- S280GD
- S320GD
- S350GD
- S550GD

A.5.9 Certified Chinese stud shear connectors

Stud shear connectors manufactured to:-

GB/T 10433-2002

A.5.10 Certified Chinese hot rolled steel bars

Any combination of steel grades manufactured to:-

GB/T 700-2006*
- Q235BZ
- Q235CZ
- Q235DTZ
- Q275BZ
- Q275CZ
- Q275DTZ

or

GB/T 1591-2008*
- Q345B
- Q345C
- Q345D
- Q345E
- Q390B
- Q390C
- Q390D
- Q390E
- Q420B
- Q420C
- Q420D
- Q420E
- Q460C
- Q460D
- Q460E
- Q500C
- Q500D
- Q500E
- Q550C
- Q550D
- Q550E
- Q620C
- Q620D
- Q620E
- Q690C
- Q690D
- Q690E

or

GB/T 4171-2008
- Q265GNH
- Q295GNH
- Q310GNH
- Q355GNHL
- Q235NH
- Q295NH
- Q355NH
- Q415NH
- Q460NH
- Q500NH
- Q550NH

with dimensional and/or mass tolerances in accordance with:-

GB/T 702-2008

A.5.11 Certified Chinese sheet piles

Sheet piles manufactured to:-

GB/T 20933-2007

Or any certified steel for cold forming (see **A.5.4**)

Appendix B Testing of steel materials

Testing of steel materials shall be in accordance with the standards given in Table B.1.

Table B.1 — Material testing required for steel materials

Tests	Materials	Parameters tested[a]	Standards for reference
Tensile test	Steel plates Hot rolled sections Hollow sections Steel for cold forming Bolts Profiled steel sheets Stud shear connectors Hot rolled bars Sheet Piles	Yield strength Tensile strength Elongation after fracture	BS EN ISO 6892-1:2009
Charpy impact test	Steel plates Hot rolled sections Hollow sections	Impact energy	BS EN ISO 148-1:2010
Hardness test	Bolts Nuts Washers	Brinell hardness Vickers hardness Rockwell hardness	BS EN ISO 6506-1:2005 BS EN ISO 6507-1:2005 BS EN ISO 6508-1:2005
Proof load test	Nuts	Proof load stress	BS EN 20898-2:1994
All-weld metal tests	Welding consumables	Yield strength Tensile strength Elongation after fracture Impact energy	BS EN ISO 15792-1:2008
Chemical analysis	Steel plates Hot rolled sections Hollow sections Steel for cold forming Bolts Profiled steel sheets Hot rolled bars Sheet Piles	Carbon content[b] Carbon equivalent value[b] Sulphur content[b] Phosphorous content[b] Others[c]	BS EN ISO 14284:2002

a To ensure the adequacy of non-certified steel materials, parameters tested shall be in compliance with the relevant material performance requirements given in **Section 2**.

b Compared to the limits specified for ladle analysis in **Section 2**, limits for product analysis shall be:-

0.03 % higher for carbon content;

0.04 % higher for carbon equivalent value;

0.01 % higher for each sulphur and phosphorous content.

c The content of the following elements shall also be determined and recorded:- silicon, manganese, copper, chromium, molybdenum, nickel, aluminium, niobium, titanium, vanadium, nitrogen and any other element intentionally added.

Appendix C Standards for reference

This appendix covers British/European, American, Japanese, Australian/New Zealand and Chinese standards used as reference materials for this design guide. The standards listed in this appendix are only current and confirmed at the time of drafting of this design guide and shall be updated in accordance with the latest version of the respective standards.

C.1 British/European standards for reference

The following British/European standards are published by the British Standards Institution, London, United Kingdom.

C.1.1 British/European standards on design of steel structures

BS 5950-1:2000	Structural use of steelwork in building — Part 1: Code of practice for design — Rolled and welded sections
BS 5950-2:2001	Structural use of steelwork in building — Part 2: Specification for materials, fabrication and erection — Rolled and welded sections
BS 5950-3.1:1990	Structural use of steelwork in building — Part 3: Design in composite construction — Section 3.1 Code of practice for design of simple and continuous composite beams
BS 5950-4:1994	Structural use of steelwork in building — Part 4: Code of practice for design of composite slabs with profiled steel sheeting
BS 5950-5:1998	Structural use of steelwork in building — Part 5: Code of practice for design of cold-formed thin gauge sections
BS 5950-6:1995	Structural use of steelwork in building — Part 6. Code of practice for design of light gauge profiled steel sheeting
BS 5950-7:1992	Structural use of steelwork in building — Part 7: Specification for materials and workmanship: cold formed sections
BS EN 1993-1-1:2005	Eurocode 3: Design of steel structures — Part 1-1: General rules and rules for buildings
BS EN 1993-1-3:2006	Eurocode 3: Design of steel structures — Part 1-3: General rules — Supplementary rules for cold-formed members and sheeting
BS EN 1993-1-8:2005	Eurocode 3: Design of steel structures — Part 1-8: Design of joints
BS EN 1993-1-12:2007	Eurocode 3: Design of steel structures — Part 1-12: Additional rules for the extension of EN 1993 up to steel grades S 700

C.1.2 British/European standards on steel materials

BS 7668:2004	Weldable structural steels — Hot finished structural hollow sections in weather resistant steels — Specification
BS EN 10020:2000	Definition and classification of grades of steel
BS EN 10021:2006	General technical delivery requirements for steel and iron products
BS EN 10025-1:2004	Hot rolled products of structural steels — Part 1: General technical delivery conditions
BS EN 10025-2:2004	Hot rolled products of structural steels — Part 2: Technical delivery conditions for non-alloy structural steels
BS EN 10025-3:2004	Hot rolled products of structural steels — Part 3: Technical delivery conditions for normalized/normalized rolled weldable fine grain structural steels
BS EN 10025-4:2004	Hot rolled products of structural steels — Part 4: Technical delivery conditions for thermomechanical rolled weldable fine grain structural steels
BS EN 10025-5:2004	Hot rolled products of structural steels — Part 5: Technical delivery conditions for structural steels with improved atmospheric corrosion resistance
BS EN 10025-6:2009	Hot rolled products of structural steels — Part 6: Technical delivery conditions for flat products of high yield strength structural steels in the quenched and tempered condition
BS EN 10027-1:2005	Designation systems for steels — Part 1: Steel names
BS EN 10079:2007	Definition of steel products
BS EN 10149-1:1996	Specification for hot-rolled flat products made of high yield strength steels for cold forming — Part 1: General delivery conditions

BS EN 10149-2:1996	Specification for hot-rolled flat products made of high yield strength steels for cold forming — Part 2: Delivery conditions for thermomechanically rolled steels
BS EN 10149-3:1996	Specification for hot-rolled flat products made of high yield strength steels for cold forming — Part 3. Delivery conditions for normalized or normalized rolled steels
BS EN 10164:2004	Steel products with improved deformation properties perpendicular to the surface of the product — Technical delivery conditions
BS EN 10210-1:2006	Hot finished structural hollow sections of non-alloy and fine grain steels — Part 1: Technical delivery conditions
BS EN 10219-1:2006	Cold formed welded structural hollow sections of non-alloy and fine grain steels — Part 1: Technical delivery conditions
BS EN 10248-1:1996	Hot rolled steel sheet piling of non alloy steels — Part 1: Technical delivery conditions
BS EN 10249-1:1996	Cold formed steel sheet piling of non alloy steels — Part 1: Technical delivery conditions
BS EN 10346:2009	Continuously hot-dip coated steel flat products — Technical delivery conditions

C.1.3 British/European standards on manufacturing tolerances

BS EN 10024:1995	Hot rolled taper flange I sections — Tolerances on shape and dimensions
BS EN 10029:2010	Specification for tolerances on dimensions, shape and mass for hot rolled steel plates 3 mm thick or above
BS EN 10034:1993	Structural steel I and H sections — Tolerances on shape and dimensions
BS EN 10051:2010	Continuously hot-rolled uncoated plate, sheet and strip of non-alloy and alloy steels — Tolerances on dimensions and shape
BS EN 10055:1996	Hot rolled steel equal flange tees with radiused root and toes — Dimensions and tolerances on shape and dimensions
BS EN 10056-2:1993	Specification for structural steel equal and unequal leg angles — Part 2: Tolerances on shape and dimensions
BS EN 10058:2003	Hot rolled flat steel bars for general purposes — Dimensions and tolerances on shape and dimensions
BS EN 10059:2003	Hot rolled square steel bars for general purposes — Dimensions and tolerances on shape and dimensions
BS EN 10060:2003	Hot rolled round steel bars for general purposes — Dimensions and tolerances on shape and dimensions
BS EN 10210-2:2006	Hot finished structural hollow sections of non-alloy and fine grain steels — Part 2: Tolerances, dimensions and sectional properties
BS EN 10219-2:2006	Cold formed welded structural hollow sections of non-alloy and fine grain steels — Part 2: Tolerances, dimensions and sectional properties
BS EN 10248-2:1996	Hot rolled steel sheet piling of non alloy steels — Part 2: Tolerances on shape and dimensions
BS EN 10249-2:1996	Cold formed steel sheet piling of non alloy steels — Part 2: Tolerances on shape and dimensions
BS EN 10279:2000	Hot rolled steel channels — Tolerances on shape, dimension and mass

C.1.4 British/European standards on bolting assemblies

General information

BS EN 20898-2:1994	Mechanical properties of fasteners — Part 2: Nuts with specified proof load values — Coarse thread
BS EN 15048-1:2007	Non-preloaded structural bolt assemblies – Part 1: General requirements

BS EN ISO 898-1:2009	Mechanical properties of fasteners made of carbon steel and alloy steel — Part 1: Bolts, screws and studs
BS EN ISO 16426:2002	Fasteners — Quality assurance system

Non-preloaded assemblies

BS 4190:2001	ISO metric black hexagon bolts, screws and nuts — Specification
BS 4320:1968	Specification for metal washers for general engineering purposes metric series
BS 7419:1991	Specification for holding down bolts
BS EN ISO 4014:2001	Hexagon head bolts — Product grades A and B
BS EN ISO 4016:2001	Hexagon head bolts — Product grade C
BS EN ISO 4017:2001	Hexagon head screws — Product grades A and B
BS EN ISO 4018:2001	Hexagon head screws — Product grade C
BS EN ISO 4032:2001	Hexagon nuts, style 1 — Product grades A and B
BS EN ISO 4033:2001	Hexagon nuts, style 2 — Product grades A and B
BS EN ISO 4034:2001	Hexagon nuts — Product grade C
BS EN ISO 7091:2000	Plain washers — Normal series — Product Grade C

Preloaded assemblies

BS 4395-1:1969	Specification for high strength friction grip bolts and associated nuts and washers for structural engineering metric series — Part 1: General grade
BS 4395-2:1969	Specification for high strength friction grip bolts and associated nuts and washers for structural engineering metric series — Part 2: Higher grade bolts and nuts and general grade washers
BS 4604-1:1970	Specification for the use of high strength friction grip bolts in structural steelwork metric series — Part 1: General grade
BS 4604-2:1970	Specification for the use of high strength friction grip bolts in structural steelwork metric series — Part 2: Higher grade (parallel shank)
BS 7644-1:1993	Direct tension indicators — Part 1: Specification for compressible washers
BS 7644-2:1993	Direct tension indicators — Part 2: Specification for nut face and bolt face washers
BS EN 14399-1:2005	High-strength structural bolting assemblies for preloading — Part 1: General requirements
BS EN 14399-2:2005	High-strength structural bolting assemblies for preloading — Part 2: Suitability test for preloading
BS EN 14399-3:2005	High-strength structural bolting assemblies for preloading — Part 3: System HR — Hexagon bolt and nut assemblies
BS EN 14399-4:2005	High-strength structural bolting assemblies for preloading — Part 4: System HV — Hexagon bolt and nut assemblies
BS EN 14399-5:2005	High-strength structural bolting assemblies for preloading — Part 5: Plain washers
BS EN 14399-6:2005	High-strength structural bolting assemblies for preloading — Part 6: Plain chamfered washers

C.1.5 British/European standards on welding consumables

BS EN 760:1996	Welding consumables — Fluxes for submerged arc welding — Classification
BS EN ISO 636:2008	Welding consumables — Rods, wires and deposits for tungsten inert gas welding of non-alloy and fine-grain steels — Classification
BS EN ISO 2560:2009	Welding consumables — Covered electrodes for manual metal arc welding of non-alloy and fine grain steels — Classification

BS EN ISO 14171:2010	Welding consumables — Solid wire electrodes, tubular cored electrodes and electrode/flux combinations for submerged arc welding of non alloy and fine grain steels — Classification
BS EN ISO 14341:2011	Welding consumables — Wire electrodes and weld deposits for gas shielded metal arc welding of non alloy and fine grain steels — Classification
BS EN ISO 14343:2009	Welding consumables — Wire electrodes, strip electrodes, wires and rods for arc welding of stainless and heat resisting steels — Classification
BS EN ISO 16834:2007	Welding consumables — Wire electrodes, wires, rods and deposits for gas shielded arc welding of high strength steels — Classification
BS EN ISO 17632:2008	Welding consumables — Tubular cored electrodes for gas shielded and non-gas shielded metal arc welding of non-alloy and fine grain steels — Classification
BS EN ISO 17633:2010	Welding consumables — Tubular cored electrodes and rods for gas shielded and non-gas shielded metal arc welding of stainless and heat-resisting steels — Classification
BS EN ISO 17634:2006	Welding consumables — Tubular cored electrodes for gas shielded metal arc welding of creep-resisting steels — Classification
BS EN ISO 18274:2010	Welding consumables — Solid wire electrodes, solid strip electrodes, solid wires and solid rods for fusion welding of nickel and nickel alloys — Classification
BS EN ISO 21952:2007	Welding consumables — Wire electrodes, wires, rods and deposits for gas-shielded arc welding of creep-resisting steel — Classification
BS EN ISO 24373:2009	Welding consumables — Solid wires and rods for fusion welding of copper and copper alloys — Classification
BS EN ISO 24598:2007	Welding consumables — Solid wire electrodes, tubular cored electrodes and electrode/flux combinations for submerged arc welding of creep-resisting steels — Classification
BS EN ISO 26304:2011	Welding consumables — Solid wire electrodes, tubular cored electrodes and electrode-flux combinations for submerged arc welding of high strength steels — Classification

C.1.6 British/European standards on profiled steel sheets

BS EN 10346:2009	Continuously hot-dip coated steel flat products — Technical delivery conditions
BS EN 10143:2006	Continuously hot-dip coated steel sheet and strip — Tolerances on dimensions and shape

C.1.7 British/European standards on stud shear connectors

BS EN ISO 13918:2008	Welding — Studs and ceramic ferrules for arc stud welding

C.1.8 British/European standards on material testing

BS EN 20898-2:1994	Mechanical properties of fasteners — Part 2: Nuts with specified proof load values — Coarse thread
BS EN ISO 148-1:2010	Metallic materials — Charpy pendulum impact test — Part 1: Test method
BS EN ISO 2566-1:1999	Steel — Conversion of elongation values — Part 1: Carbon and low alloy steels
BS EN ISO 6506-1:2005	Metallic materials — Brinell hardness test — Part 1: Test method
BS EN ISO 6507-1:2005	Metallic materials — Vickers hardness test — Part 1: Test method
BS EN ISO 6508-1:2005	Metallic materials — Rockwell hardness test — Part 1: Test method (scales A, B, C, D, E, F, G, H, K, N, T)
BS EN ISO 6892-1:2009	Metallic materials — Tensile testing — Part 1: Method of test at ambient temperature
BS EN ISO 8501-1:2007	Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Rust grades and

	preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings
BS EN ISO 14284:2002	Steel and iron — Sampling and preparation of samples for the determination of chemical composition
BS EN ISO 15792-1:2008	Welding consumables — Test methods — Part 1: Test methods for all-weld metal test specimens in steel, nickel and nickel alloys

C.1.9 British/European standards on inspection documents

BS EN 10168:2004	Steel products — Inspection documents — List of information and description
BS EN 10204:2004	Metallic products — Types of inspection documents

C.2 American standards for reference

The following American standards are published by the American Institute of Steel Construction, Chicago, Illinois; the American Petroleum Institute, Washington, D.C.; the American Society for Testing and Materials, West Conshohocken, Pennsylvania; the American Welding Society, Miami, Florida, United States of America.

C.2.1 American standards on design of steel structures

AISC 303-2010	Code of Standard Practice for Steel Buildings and Bridges
ANSI/AISC 360-2010	Specification for Structural Steel Buildings

C.2.2 American standards on steel materials

API 5L–2010	Specification for Line Pipe
ASTM A 36–2008	Standard Specification for Carbon Structural Steel
ASTM A 53–2010	Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
ASTM A 109–2008	Standard Specification for Steel, Strip, Carbon (0.25 Maximum Percent), Cold-Rolled
ASTM A 242–2004(09)	Standard Specification for High-Strength Low-Alloy Structural Steel
ASTM A 268–2010	Standard Specification for Seamless and Welded Ferritic and Martensitic Stainless Steel Tubing for General Service
ASTM A 283–2003(07)	Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates
ASTM A 308–2010	Standard Specification for Steel Sheet, Terne (Lead-Tin Alloy) Coated by the Hot-Dip Process
ASTM A 328–2007	Standard Specification for Steel Sheet Piling
ASTM A 333–2010	Standard Specification for Seamless and Welded Steel Pipe for Low-Temperature Service
ASTM A 423–2009	Standard Specification for Seamless and Electric-Welded Low-Alloy Steel Tubes
ASTM A 500–2010a	Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
ASTM A 501–2007	Standard Specification for Hot-Formed Welded and Seamless Carbon Steel Structural Tubing
ASTM A 514–2005(09)	Standard Specification for High-Yield-Strength, Quenched and Tempered Alloy Steel Plate, Suitable for Welding
ASTM A 529–2005(09)	Standard Specification for High-Strength Carbon-Manganese Steel of Structural Quality
ASTM A 572–2007	Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel
ASTM A 573–2005(09)	Standard Specification for Structural Carbon Steel Plates of Improved Toughness
ASTM A 588–2010	Standard Specification for High-Strength Low-Alloy Structural Steel with 50 ksi [345 MPa] Minimum Yield Point to 4–in. [100–mm] Thick
ASTM A 595–2006	Standard Specification for Steel Tubes, Low-Carbon or High-Strength Low-Alloy, Tapered for Structural Use
ASTM A 606–2009a	Standard Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, with Improved Atmospheric Corrosion Resistance
ASTM A 618–2004(10)	Standard Specification for Hot-Formed Welded and Seamless High-Strength Low-Alloy Structural Tubing

ASTM A 653–2010	Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
ASTM A 673–2007	Standard Specification for Sampling Procedure for Impact Testing of Structural Steel
ASTM A 709–2010	Standard Specification for Structural Steel for Bridges
ASTM A 792–2010	Standard Specification for Steel Sheet, 55 % Aluminum-Zinc Alloy-Coated by the Hot-Dip Process
ASTM A 847–2005	Standard Specification for Cold-Formed Welded and Seamless High-Strength, Low- Alloy Structural Tubing with Improved Atmospheric Corrosion Resistance
ASTM A 852–2003(07)	Standard Specification for Quenched and Tempered Low-Alloy Structural Steel Plate with 70 ksi [485 MPa] Minimum Yield Strength to 4 in. [100 mm] Thick
ASTM A 857–2007	Standard Specification for Steel Sheet Piling, Cold Formed, Light Gage
ASTM A 871–2003(07)	Standard Specification for High-Strength Low-Alloy Structural Steel Plate With Atmospheric Corrosion Resistance
ASTM A 875–2010	Standard Specification for Steel Sheet, Zinc-5 % Aluminum Alloy-Coated by the Hot-Dip Process
ASTM A 913–2011	Standard Specification for High-Strength Low-Alloy Steel Shapes of Structural Quality, Produced by Quenching and Self-Tempering Process (QST)
ASTM A 945–2006	Standard Specification for High-Strength Low-Alloy Structural Steel Plate with Low Carbon and Restricted Sulfur for Improved Weldability, Formability, and Toughness
ASTM A 992–2011	Standard Specification for Structural Steel Shapes
ASTM A 1003–2010	Standard Specification for Steel Sheet, Carbon, Metallic- and Nonmetallic-Coated for Cold-Formed Framing Members
ASTM A 1008–2010	Steel, Sheet, Cold-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, Solution Hardened, and Bake Hardenable
ASTM A 1011–2010	Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability
ASTM A 1066–2011	Standard Specification for High-Strength Low Alloy Structural Steel Plate Produced by Thermo-Mechanical Controlled Process (TMCP)

C.2.3 American standards on manufacturing tolerances

ASTM A 6–2010a	Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling
ASTM A 450–2010	Standard Specification for General Requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes
ASTM A 568–2009a	Standard Specification for Steel, Sheet, Carbon, Structural, and High-Strength, Low- Alloy, Hot-Rolled and Cold-Rolled, General Requirements for
ASTM A 924–2010a	Standard Specification for General Requirements for Steel Sheet, Metallic-Coated by the Hot-Dip Process
ASTM A 999–2004a(09)	Standard Specification for General Requirements for Alloy and Stainless Steel Pipe

C.2.4 American standards on bolting assemblies

Non-preloaded assemblies

ASTM A 193–2010a	Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service

ASTM A 194–2010a	Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
ASTM A 307–2010	Standard Specification for Carbon Steel Bolts and Studs, 60 000 psi Tensile Strength
ASTM A 325M–2009	Standard Specification for Structural Bolts, Steel, Heat Treated 830 MPa Minimum Tensile Strength [Metric]
ASTM A 354–2007a	Standard Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners
ASTM A 449–2010	Standard Specification for Hex Cap Screws, Bolts and Studs, Steel, Heat Treated, 120/105/90 ksi Minimum Tensile Strength, General Use
ASTM A 490M–2010	Standard Specification for High-Strength Steel Bolts, Classes 10.9 and 10.9.3, for Structural Steel Joints [Metric]
ASTM A 563M–2007	Standard Specification for Carbon and Alloy Steel Nuts [Metric]
ASTM F 436M–2010	Standard Specification for Hardened Steel Washers [Metric]

Preloaded assemblies

ASTM A 193–2010a	Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service
ASTM A 194–2010a	Standard Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
ASTM A 354–2007a	Standard Specification for Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners
ASTM A 563M–2007	Standard Specification for Carbon and Alloy Steel Nuts [Metric]
ASTM F 436M–2010	Standard Specification for Hardened Steel Washers [Metric]
ASTM F 959M–2007	Standard Specification for Compressible-Washer-Type Direct Tension Indicators for Use with Structural Fasteners [Metric]
ASTM F 1852–2008	Standard Specification for "Twist Off" Type Tension Control Structural Bolt/Nut/Washer Assemblies, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength

C.2.5 American standards on welding consumables

AWS D1.3–2008	Structural welding code – Sheet steel
AWS A5.1:2004	Specifications for carbon steel electrodes for shielded metal arc-welding
AWS A5.9:2005	Specification for low-alloy steel electrodes for flux cored arc welding

C.2.6 American standards on profiled steel sheets

ASTM A 606–2009a	Standard Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, with Improved Atmospheric Corrosion Resistance
ASTM A 653–2010	Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
ASTM A 1046–2010a	Standard Specification for Steel Sheet, Zinc-Aluminum-Magnesium Alloy-Coated by the Hot-Dip Process

C.2.7 American standards on shear stud connectors

ASTM A 29–2005	Standard Specification for Steel Bars, Carbon and Alloy, Hot-Wrought, General Requirements for
AWS D1.1–2010	Structural Steel Welding Code – Steel

C.3 Japanese standards for reference

The following Japanese standards are published by the Japanese Industrial Standards Committee, Tokyo, Japan.

C.3.1 Japanese standards on design of steel structures

JSCE: 1997	Design Code for Steel Structures – Part A: Structures in General
JSCE: 1997	Design Code for Steel Structures – Part B: Composite Structures

C.3.2 Japanese standards on steel materials

JIS A 5523:2006	Weldable hot rolled steel sheet piles
JIS A 5525:2004	Steel pipe piles
JIS A 5528:2006	Hot rolled steel sheet piles
JIS A 5530:2010	Steel pipe sheet piles
JIS G 3101:2010	Rolled steels for general structure
JIS G 3106:2008	Rolled steels for welded structure
JIS G 3114:2008	Hot-rolled atmospheric corrosion resisting steels for welded structure
JIS G 3128:2009	High yield strength steel plates for welded structure
JIS G 3131:2010	Hot-rolled mild steel plates, sheets and strip
JIS G 3132:2005	Hot-rolled carbon steel strip for pipes and tubes
JIS G 3136:2005	Rolled steels for building structure
JIS G 3302:2010	Hot-dip zinc coated steel sheets and coils
JIS G 3312:2008	Prepainted hot-dip zinc-coated steel sheets and coils
JIS G 3321:2010	Hot-dip 55 % aluminium-zinc alloy-coated steel sheets and coils
JIS G 3322:2008	Prepainted hot-dip 55 % aluminium-zinc alloy-coated steel sheets and coils
JIS G 3350:2009	Light gauge sections for general structure
JIS G 3352:2003	Steel decks
JIS G 3444:2010	Carbon steel tubes for general structural purposes
JIS G 3466:2010	Carbon steel square pipes for general structural purposes
JIS G 3475:2008	Carbon steel tubes for building structure

C.3.3 Japanese standards on manufacturing tolerances

JIS G 3191:2010	Dimensions, mass and permissible variations of hot rolled steel bars in coil
JIS G 3192:2010	Dimensions, mass and permissible variations of hot rolled steel sections
JIS G 3193:2008	Dimensions, mass and permissible variations of hot rolled steel plates, sheets and strip
JIS G 3194:2010	Dimensions, mass and permissible variations of hot rolled flat steel

C.3.4 Japanese standards on bolting assemblies

Non-preloaded assemblies

JIS B 1051:2000	Mechanical properties of fasteners made of carbon steel and alloy steel
JIS B 1052-2:2009	Mechanical properties of fasteners – Part 2: Nuts with specified proof load values – Coarse thread
JIS B 1052-6:2009	Mechanical properties of fasteners – Part 6: Nuts with specified proof load values – Fine pitch thread

JIS B 1180:2009	Hexagon head bolts and hexagon head screws
JIS B 1181:2009	Hexagon nuts and hexagon thin nuts
JIS B 1256:2008	Plain washers

Preloaded assemblies

JIS B 1186:2007	Sets of high strength hexagon bolt, hexagon nut and plain washer for friction grip joints
JSS II-09:1981	Sets of torshear type high strength bolt, hexagon nut and plain washer for structural joints

C.3.5 Japanese standards on welding consumables

JIS Z 3200:2005	Welding consumables – Technical delivery conditions for welding filler materials – Type of product, dimensions, tolerances and markings
JIS Z 3211:2008	Covered electrodes for mild steel, high tensile strength steel and low temperature service steel
JIS Z 3212:2000	Covered electrodes for high tensile strength steel
JIS Z 3313:2009	Flux cored wires for gas shielded and self-shielded metal arc welding of mild steel, high strength steel and low temperature service steel

C.3.6 Japanese standards on profiled steel sheets

JIS G 3302:2010	Hot-dip zinc coated steel sheets and coils
JIS G 3317:2010	Hot-dip zinc-5% aluminium alloy-coated steel sheet and strip
JIS G 3321:2010	Hot-dip 55 % aluminium-zinc alloy-coated steel sheet and strip

C.3.7 Japanese standards on stud shear connectors

JIS B 1198:2011	Headed studs

C.4 Australian/New Zealand standards for reference

The following Australian/New Zealand standards are published by Standards Australia, Sydney, Australia.

C.4.1 Australian/New Zealand standards on design of steel structures

AS 4100-1998	Steel structures

C.4.2 Australian/New Zealand standards on steel materials

AS/NZS 1163-2009	Structural steel hollow sections (cold-formed)
AS 1397-2001	Steel sheet and strip – Hot-dipped zinc-coated or aluminium/zinc-coated
AS 1548-2008	Steel plate for pressure equipment
AS/NZS 1594-2002	Hot-rolled steel flat products
AS/NZS 1595-1998	Cold-rolled, unalloyed, steel sheet and strip
AS/NZS 3678-2011	Structural steel – hot-rolled plates, floor plates and slabs
AS/NZS 3679.1-2010	Structural steel – Part 1: Hot-rolled bars and sections

C.4.3 Australian/New Zealand standards on manufacturing tolerances

AS/NZS 1365-1996	Tolerances for flat rolled steel products
AS 1548-2008	Steel plate for pressure equipment
AS/NZS 3679.1-2010	Structural steel – Part 1: Hot-rolled bars and sections

C.4.4 Australian/New Zealand standards on bolting assemblies

AS 1110.1-2000	ISO metric hexagon bolts and screws – Product grades A and B Part 1: Bolts
AS 1110.2-2000	ISO metric hexagon bolts and screws – Product grades A and B Part 2: Screws
AS 1111.1-2000	ISO metric hexagon bolts and screws – Product grade C Part 1: Bolts
AS 1111.2-2000	ISO metric hexagon bolts and screws – Product grade C Part 2: Screws
AS 1112.1-2000	ISO metric hexagon nuts – Part 1: Style 1 – Product grades A and B
AS 1112.2-2000	ISO metric hexagon nuts – Part 2: Style 2 – Product grades A and B
AS 1112.3-2000	ISO metric hexagon nuts – Part 3: Product grade C
AS 1112.4-2000	ISO metric hexagon nuts – Part 4: Chamfered thin nuts. Product grades A and B
AS 4291.1-2000	Mechanical properties of fasteners made of carbon steel and alloy steel – Bolts, screws and studs
AS/NZS 1252-1996	High strength steel bolts with associated nuts and washers for structural engineering
AS/NZS 1559-1997	Hot-dip galvanized steel bolts with associated nuts and washers for tower construction.
AS/NZS 4291.2-1995	Mechanical properties of fasteners – Nuts with specified proof load values – Coarse thread

C.4.5 Australian/New Zealand standards on welding consumables

AS 1554.1-2004	Structural Steel Welding – Welding of steel structures
AS/NZS 4855-2007	Manual arc weld
AS/NZS 4857-2006	Manual arc weld high strength steel
AS/NZS 1167.2-1999	Welding and brazing – Filler metals
AS/NZS 2717.1-1996	Welding – Electrodes – Gas metal arc

AS 1858.1-2003	Electrodes and fluxes for submerged-arc welding – Carbon steels and carbon-manganese steels

C.4.6 Australian/New Zealand standards on profiled steel sheets

AS 1397-2001	Steel sheet and strip – Hot-dipped zinc-coated or aluminium/zinc-coated

C.4.7 Australian/New Zealand standards on shear stud connectors

AS/NZS 1554.2-2003	Structural steel welding – Stud welding

C.5 Chinese standards for reference

The following Chinese standards are published by the Standardization Administration of China, Beijing, People's Republic of China.

C.5.1 Chinese standards on design of steel structures

GB 50017-2003	Code for design of steel structures
GB 50018-2002	Technical code of cold-formed thin-wall steel structures
JGJ 81-2002	Technical specification for welding of steel structure of building
JGJ 82-1991	Code for design, construction and acceptance of high strength bolt connection of steel structures

C.5.2 Chinese standards on steel materials

GB/T 700-2006	Carbon structural steels
GB 912-2008	Hot-rolled sheets and strips of carbon structural steels and high strength low alloy structural steels
GB/T 1591-2008	High strength low alloy structural steels
GB/T 3274-2007	Carbon structural and low alloy steel rolled plates and strips
GB/T 4171-2008	Atmospheric corrosion resisting structural steel
GB/T 4172-2000	Atmospheric corrosion resisting steel for welded structures
GB/T 5313-2010	Steel plate with through-thickness characteristics
GB/T 8162-2008	Seamless steel tubes for structural purposes
GB/T 13304.1-2008	Steels classification – Part 1: Classification of according to chemical composition
GB/T 13304.2-2008	Steels classification – Part 2: Classification of according to main quality classes and main property or application characteristics
GB/T 15574-1995	Steel products classification and definitions
GB/T 19879-2005	Steel plates for building structure
GB/T 20933-2007	Hot rolled U-sheet pile
YB 4104-2000	Steel plates for high rise building structure

C.5.3 Chinese standards on manufacturing tolerances

GB/T 702-2008	Hot-rolled steel bars – Dimensions, shape, weight and tolerances
GB/T 706-2008	Hot rolled section steel
GB/T 707-1988	Hot-rolled channel steel – Dimensions, shape, weight and tolerances
GB/T 709-2006	Dimension, shape, weight and tolerances for hot-rolled steel plates and sheets
GB/T 6728-2002	Cold formed steel hollow sections for general structure – Dimensions, shapes, weight and permissible deviations
GB/T 9787-1988	Hot-rolled equal-leg angle steel – Dimensions, shape, weight and tolerances
GB/T 9946-1988	Dimensions, shape, weight and tolerances for hot-rolled L-sectional steel
GB/T 11263-2010	The hot-rolled H and cut T section
GB/T 17395-2008	Dimensions, shapes, masses and tolerances of seamless steel tubes

C.5.4 Chinese standards on bolting assemblies

General information

GB/T 3098.1-2010	Mechanical properties of fasteners – Bolts, screws and studs

GB/T 3098.2-2000	Mechanical properties of fasteners – Nuts – Coarse thread

Materials

GB/T 699-1999	Quality carbon structural steels
GB/T 3077-1999	Alloy structure steels
GB/T 6478-2001	Steels for cold heading and cold extruding

Non-preloaded assemblies

GB/T 41-2000	Hexagon nuts – Product grade C
GB/T 95-2002	Plain washers – Product grade C
GB/T 5780-2000	Hexagon head bolts – Product grade C
GB/T 5781-2000	Hexagon head bolts – Full thread – Product grade C
GB/T 5782-2000	Hexagon head bolts
GB/T 5783-2000	Hexagon head bolts – Full thread
GB/T 6170-2000	Hexagon nuts, style 1
GB/T 6175-2000	Hexagon nuts, style 2

Preloaded assemblies

GB/T 1228-2006	High strength bolts with large hexagon head for steel structures
GB/T 1229-2006	High strength large hexagon nuts for steel structures
GB/T 1230-2006	High strength plain washers for steel structures
GB/T 1231-2006	Specifications of high strength bolts with large hexagon nuts, plain washers for steel structures
GB/T 3632-2008	Sets of torshear type high strength bolt hexagon nut and plain washer for steel structures
GB/T 3633-1995	Technical requirement for sets of torshear type high strength bolt hexagon nut and plain washer for steel structures

C.5.5 Chinese standards on welding consumables

GB/T 3429-2002	Wire rod for electrode
GB/T 5117-1995	Carbon steel covered electrodes
GB/T 5118-1995	Low alloy steel covered electrodes
GB/T 5293-1999	Carbon steel electrodes and fluxes for submerged arc welding
GB/T 8110-2008	Welding wires for gas shielding arc welding of carbon and low alloy steels
GB/T 10045-2001	Carbon steel flux cored electrodes for arc welding
GB/T 12470-2003	Low alloy steel electrodes and fluxes for submerged arc welding
GB/T 14957-1994	Steel wires for melt welding
GB/T 14981-2009	Dimensions, shape, mass and tolerances for hot-rolled wire rods
GB/T 17493-2008	Low alloy steel flux cored electrodes for arc welding

C.5.6 Chinese standards on profiled steel sheets

GB/T 2518-2008	Continuous hot-dip zinc-coated steel sheets and strips
GB/T 12755-2008	Roll-profiled steel sheet for building

C.5.7 Chinese standards on stud shear connectors

GB/T 10433-2002	Cheese head studs for arc stud welding

We shape a **safe**, **high quality**, **sustainable** and **friendly** built environment.

5 Maxwell Road #05-00
Tower Block MND Complex
Singapore 069110
Tel: 1800-3425222 (1800-DIAL-BCA)
+65 6534 0219 (For overseas call)
Fax: +65 63254800
Website: www.bca.gov.sg