3 MATERIALS

3.1 STRUCTURAL STEEL

3.1.1 General

This clause covers the design of structures fabricated from normal strength structural steels with a design strength not exceeding 460 N/mm^2 from one of the following classes:

Class 1: Steel complying with one of the reference material standards in Annex A1.1 and basic requirements given in clause 3.1.2 and produced from a manufacturer with an acceptable Quality Assurance system.

Class 2: Steel which has not been manufactured to one of the reference material standards in Annex A1.1 but is produced from a manufacturer with an acceptable Quality Assurance system. Such steel shall be tested to show that it complies with one of the reference material standards in Annex A1.1 before being used. Requirements on the sampling rate for testing are given in Annex D1.

Class 3: Uncertified steel; steel not covered by Class 1, Class 2. Tensile tests shall be carried out on such steel to show that it fulfils the intended design purpose before being used. Requirements on the sampling rate for testing are given in Annex D1. Restrictions and limited applications are imposed on the use of this material, see clause 3.1.4.

Hot rolled steels and cold-formed structural hollow sections are covered in clause 3.1 and cold formed steel open sections and profiled sheets are covered in clause 3.8.

Class 1H: High strength steels with yield strengths greater than 460 N/mm^2 but less than or equal to 690 N/mm^2 and complying with one of the reference material standards in Annex A1.1. Basic requirements for the steel and producer are given in clause 3.1.2 and high strength steels shall be produced from a manufacturer with an acceptable Quality Assurance system.

Class UH: Ultra high strength steels with yield strengths greater than 690 N/mm^2 are not covered by the Code. Subject to the approval of the Building Authority, they may be used in bolted tension applications in the form of proprietary high strength tie rods or bars, or in other applications. In these cases, the Responsible Engineer shall provide a full justification and ensure that all requirements are met in the submission of this material to the Building Authority.

The Code covers both elastic and plastic analysis and design. Plastic analysis and design is not permitted for uncertified steels or for steels with yield strength greater than 690 N/mm^2.

High strength steels may give advantages for certain ultimate limit states such as compression resistances in heavily loaded columns and moment resistances in long span beams, but with limited improvement in very slender columns undergoing primarily elastic buckling. Pre-cambering may be adopted to reduce beam deflections under dead and imposed loads. Their use does not improve the performance for fatigue and serviceability limit states.

For a particular project, it is good practice to use steel from one source of supply.

Table 3.1 - Strength grade summary table

Strength Grade	***Class***	***Acceptable Quality Assurance system***	***Compliance with reference material Standard***	***Additional test Required***	***Remarks***
$Y_s \leq 460$	1	Y	Y	N	Normal use
	2	Y	N	Y	Can be used subject to satisfactory tests
	3	N	-	Y	Restricted use with limited applications
$460 < Y_s \leq 690$	1H	Y	Y	N	Normal use

Note: Reference standards refer to acceptable standards adopted in Australia, China, Japan, United States of America and British versions of European Union Standards. For sampling rate of testing frequency, refer to Annex D1.

3.1.2 Design strength for normal strength steels and high strength steels

The design strength, p_y, for steel is given by:

$$p_y = \frac{Y_S}{\gamma_{m1}} \text{ but not greater than } \frac{U_S}{\gamma_{m2}}$$

where

Y_s the yield strength is defined as:

(a) the upper yield strength, R_{eH}, the stress at the initiation of yielding for steel materials with clearly defined yield point; or

(b) if the yield point cannot be clearly defined, then the 0.2% proof stress, $R_{p\,0.2}$, or the stress at 0.5% total elongation, $R_{t\,0.5}$ for steel materials whichever is smaller.

(c) In case of dispute, the 0.2% proof stress, $R_{p\,0.2}$, shall be adopted.

U_S is the minimum tensile strength, R_m .

γ_{m1} , γ_{m2} are the material factors given in Table 4.1. These material factors are minimum values and the design strengths should not be greater than those given in the respective material standards.

For the more commonly used grades and thicknesses of Class 1 steels supplied in accordance with European BS EN, Chinese GBJ, American ASTM, Australian AS and Japanese JIS standards for hot rolled steel, the value of design strength p_y is given in Tables 3.2 to 3.6 respectively. Alternatively, the design strength p_y may be obtained from the formula above using values of minimum yield strength and minimum tensile strength given in the relevant steel product standard, see Annex A1.1. (The design strengths should not be greater than those given in the respective material standards.)

The Code requires that steel product manufacturers produce sections to their stated nominal sizes within their specified +/- tolerances such that average section sizes and properties are at least the nominal values. The Responsible Engineer shall ensure that any steel used complies with this or he shall take into account of any adverse variation in his design.

The essentials of the basic requirements for normal strength steels are:

- **Strength:**
  The design strength shall be the minimum factored yield strength Y_z/γ_{m1} but not greater than the minimum tensile strength U_s/γ_{m2} where γ_{m1} and γ_{m2} are given in Table 4.1.

Resistance to brittle fracture:

The minimum average Charpy V-notch impact test energy at the required design temperature shall be in accordance with clause 3.2 of the Code in order to provide sufficient notch toughness.

- **Ductility:**
  The elongation on a gauge length of $5.65\sqrt{S_o}$ where S_o is the cross sectional area of the section, should be as follows:

  For Classes 1 and 2 steel, the elongation at fracture is not to be less than 15%;

  For Class 1H steel, the elongation at fracture is not to be less than 10%; and

  The strain at the tensile strength should not be greater than 15 times the strain at the yield strength.

- **Weldability:**
  The chemical composition and maximum carbon equivalent value for Classes 1, 2 and 1H steel shall conform to the respective reference materials standard in Annex A1.1.

  The minimum requirements on the chemical composition of the materials for Class 3 steel when welding is involved are as follows:

  a) The maximum carbon equivalent value shall not exceed 0.48% on ladle analysis and the carbon content shall not exceed 0.24%;

  b) For general applications, the maximum sulphur content shall not exceed 0.03% and the maximum phosphorus content shall not exceed 0.03%; and

  c) When through thickness quality (Z quality) steel is specified, the sulphur content shall not exceed 0.01%.

  The chemical compositions of various grades of steel shall also conform to the requirements stipulated in the national material standards to which where they are manufactured.

For cold-formed thin gauge steel open sections and sheet profiles as stipulated in clauses 11.1 to 11.6, only the basic requirements on strength and ductility are applicable as given in clauses 3.8.1.1 and 3.8.1.2. Typical design strengths for cold-formed thin gauge steel open sections and sheet profiles are given in clause 3.8.1.1.

For cold-formed steel hollow sections as stipulated in clause 11.7, the basic requirements on strength and ductility are applicable as given in this clause. For cold-formed steel pile sections as stipulated in clause 11.8, the basic requirements on strength and ductility are also applicable as given in this clause.

Table 3.2 - Design strength p_y for steels supplied in accordance with BS EN standards (plates, hot rolled sections, hot finished and cold formed hollow sections, cold formed sections and profiled sheets)

Steel grade	Thickness less than or equal to (mm)	Design strength p_y (N/mm^2)
S235	16	235
	40	225
	63	215
	80	215
	100	215
	150	205
S275	16	275
	40	265
	63	255
	80	245
	100	235
	150	225
S355	16	355
	40	345
	63	335
	80	325
	100	315
	150	295
S450	16	450
	40	430
	63	410
	80	390
	100	380
S460	16	460
	40	440
	63	430
	80	410
	100	400
S550	50	550
	100	530
	150	490
S690	50	690
	100	650
	150	630

Note that the thickness of the thickest element of the cross section should be used for strength classification of rolled sections.

Table 3.3 - Design strength p_y for steels supplied in accordance with Chinese standard GB50017 (plates, hot rolled sections, hot finished and cold formed hollow sections, cold formed sections and profiled sheets)

a) Q235 ~ Q460 steel

Steel grade	Thickness less than or equal to (mm)	Design strength p_y (N/mm^2)
Q235	16	215
	40	205
	100	200
Q345/Q355	16	305
	40	295
	63	290
	80	280
	100	270
Q390	16	345
	40	330
	63	310
	100	295
Q420	16	375
	40	355
	63	320
	100	305
Q460	16	410
	40	390
	63	355
	100	340

b) Q550 ~ Q690 steel

Steel grade	Thickness less than or equal to (mm)	Design strength p_y (N/mm^2)
Q550	16	520
	40	500
	63	475
	80	455
	100	445
Q690	16	630
	40	615
	63	605
	80	585

Table 3.4 - Design strength p_y for North American steel supplied to ASTM Standards (plates, hot rolled sections, hot finished and cold formed hollow sections, cold formed sections and profiled sheets)

Steel grade	Thickness less than or equal to (mm)	Design strength p_y (N/mm^2)
ASTM A36	200	250
	>200	220
ASTM A 572 Grade 50	All	345
ASTM A500 Grade B	All above 4.6 mm, Circular Hollow Sections	290
	All above 4.6 mm, Rectangular Hollow Sections	315
ASTM A992 Grade 50	All, Hot Rolled Shapes	345
ASTM A913 Grade 50	All, Quenched & Self Tempered	345
ASTM A913 Grade 60	All, Quenched & Self Tempered	415
ASTM A913 Grade 65	All, Quenched & Self Tempered	450

Note that a wide range of steel are available to American standards, see also references in Annex A1.1. This Table contains a summary range of strengths for easy reference. Refer to the particular ASTM material standard for that particular steel for its design strength value.

Table 3.5 - Design strength p_y for steels supplied in accordance with Australian standards (plates, hot rolled sections, hot finished and cold formed hollow sections, cold formed sections and profiled sheets)

Steel grade	Design strength range, dependant on thickness p_y (N/mm^2)
200	200
250	230 – 250
300	280 – 300
350	320 – 350
400	380 – 400
450	420 – 450

Note that a wide range of steel are available to Australian standards, see references in Annex A1.1. Plates, rolled sections and hollow sections are typically available with designated grades from 200 to 450 and with yield strengths from 200 N/mm^2 to 450 N/mm^2. This Table contains a summary range of strengths for easy reference. Refer to the particular Australian material standard for that particular steel for its design strength value.

Table 3.6 - Design strength p_y for Japanese JIS SN Steel (rolled steel for building products) to JIS G 3136 supplied in accordance with JIS standards (plates, hot rolled sections, hot finished and cold formed hollow sections, cold formed sections and profiled sheets)

Steel grade	Thickness less than or equal to (mm)	Design strength p_y (N/mm^2)
SN400A	16	235
	40	235
	100	215
SN400B	16	235
	40	235
	100	215
SN400C	16	235
	40	235
	100	235
SN490B	16	325
	40	325
	100	295
SN490C	16	325
	40	325
	100	295

Note that a wide range of steel are available to Japanese standards, see also references in Annex A1.1. This Table contains a summary range of strengths from the most recent SN range to JIS G 3136. Refer to the particular JIS material standard for that particular steel for its design strength value. Note that JIS G 3136 gives an upper limit to the steel yield strength which is applicable for seismic design.

3.1.3 Design strength for ultra high strength steels

For ultra high strength steels with a design strength greater than 690 N/mm^2 produced in accordance with the basic requirements in Annex D1.1, the design strength p_y may be taken as Y_s/γ_{m1} but not greater than U_s/γ_{m2}, where Y_s and U_s are respectively the minimum yield strength (R_{eH}) and minimum tensile strength (R_m) specified in the relevant reference material standard or derived by the manufacturer using an acceptable Quality Assurance system, while γ_{m1} and γ_{m2} are the material factors according to manufacturer's recommendations.

These materials typically obtain their strength through a quenching and tempering heat-treatment or a thermo-mechanically controlled process. There are additional restraints on fabrication and design, particularly with welding, because heat may affect the strength of the parent steel.

3.1.4 Uncertified steel

If Class 3 uncertified steel is used, it shall be free from surface imperfections and shall comply with all geometric tolerance specifications and shall be used only where the particular physical properties of the steel and its weldability will not affect the strength and serviceability of the structure. The design strength, p_y, shall be taken as 170 N/mm^2, subject to verification by testing as described in Annex D1.

The steel shall not be used in the primary structural elements of multi-storey buildings or in the primary structure of single storey buildings with long spans. Primary structural element is defined as main beams spanning directly onto columns, any beams over 6 m span, columns supporting a floor area of more than 25 m^2 or elements of lateral load resisting structural systems.

The steel shall only be used with elastic design methods for analysis and section capacity. The steel shall not be welded unless adequate tests on mechanical properties, chemical composition and hardness have demonstrated its suitability, see clause 3.1.2 and Annex D1.

3.1.5 Through thickness properties

The essential requirement is an adequate deformation capacity perpendicular to the plate surface to provide ductility and toughness against fracture under tension

The design strengths given in most material specifications refer to the longitudinal and transverse directions. Where there are through thickness tensile stresses greater than 90% of the design strength, through thickness properties as defined in acceptable references in Annex A1.1 should be specified to ensure structural adequacy. For thick T butt welds or for heavy double fillet welded joints, consideration should be given to specifying steel with guaranteed through thickness tensile properties to reduce the risk of lamellar tearing (see also clause 9.2.1).

The essential requirement is an adequate deformation capacity perpendicular to the surface to provide ductility and toughness against fracture.

3.1.6 Other properties

In carrying out the analysis, the following properties of steel may be used:

Modulus of elasticity	$E = 205,000$ N/mm^2
Shear modulus	$G = E/[2(1+\nu)]$
Poisson's ratio	$\nu = 0.3$
Coefficient of linear thermal expansion	$\alpha = 14 \times 10^{-6}$/°C
Density	7850 kg/m^3

3.2 PREVENTION OF BRITTLE FRACTURE

Brittle fracture should be avoided by ensuring fabrication is free from significant defects and by using a steel quality with adequate notch toughness as quantified by the Charpy impact properties. The factors to be considered include the minimum service temperature, the thickness, the steel grade, the type of detail, the stress level and the strain rate.

The welding consumables and welding procedures should also be chosen to ensure the Charpy impact test properties in the weld metal and the heat affected zone of the joint that are equivalent to, or better than the minimum specified for the parent material, see clause 3.4 and clause 14.3.

In Hong Kong the minimum service temperature T_{min} in the steel should normally be taken as 0.1°C for external steelwork. For locations subject to exceptionally low temperatures, such as cold storage or structures to be constructed in other countries, T_{min} should be taken as the minimum temperature expected to occur in the steel within the design working life.

The guidance given in this section should be used for the selection of material for new construction. It is not intended to cover the assessment of materials in service. The rules should be used to select a suitable grade of steel from the steel products as listed in Annex A1.

The rules are applicable to tension elements, welded and fatigue stressed elements in which some portion of the stress cycle is tensile. Fracture toughness need not be specified for elements only in compression.

The rules shall be applied to the properties of materials specified for the toughness quality in the relevant steel product standard. Material of a less onerous grade shall not be used even though test results show compliance with the specific grade.

3.2.1 Procedure

3.2.1.1 The steel grade should be selected after taking account of:

a) Steel material properties:
   - Yield strength depending on the material thickness $p_y(t)$
   - Toughness quality expressed in terms of T and J_{min}
     where T is the temperature under Charpy impact test; and
     J_{min} is the guaranteed value of Charpy impact energy

b) Member characteristics:
   - Member shape and detail
   - Element thickness (t)

c) Design situations:
   - Design value of minimum service temperature, T_{min}
   - Maximum stress σ derived from the design condition described in clause 3.2.1.3 below
   - For cold-formed steel sections with significant transverse bending, for example, cold-formed circular and rectangular hollow sections, the minimum service temperature should be reduced by 5°C.

3.2.1.2 The permitted thickness of steel elements against brittle fracture should be obtained from clause 3.2.2 and Table 3.7.

3.2.1.3 The maximum stress σ derived of each structural element or connection should be determined by elastic analysis after considering various load combination including temperature effect under serviceability limit states in accordance with clause 4.3.7.

3.2.1.4 The maximum stress σ is determined using an elastic analysis under serviceability limit states.

3.2.2 Determination of maximum permissible values of element thickness

Table 3.7 gives the maximum permissible values of element thickness in terms of three stress levels expressed as proportions of the nominal yield strength:

a) $\sigma = 0.75 p_y(t)$ [N/mm²]

b) $\sigma = 0.50 p_y(t)$ [N/mm²]

c) $\sigma = 0.25 p_y(t)$ [N/mm²]

where $p_y(t)$ may be determined either from

$$p_y(t) = p_y - 0.25t \; [N/mm^2]$$

where t is the thickness of the plate in mm or taken as R_{eH}-values from the relevant steel material specifications or standards.

The tabulated values are given in terms of a choice of seven reference temperatures: +10, 0, -10, -20, -30, -40 and -50ºC.

Table 3.7 Maximum permissible values of element thickness t in mm

Steel grade	Sub-grade EN	Sub-grade GBJ, ASTM, JIS, AS, NZ	Delivery condition	Charpy impact energy at T [°C]	Charpy impact energy J_{min}	σ = 0,75 $p_y(t)$, T_{min} [°C] 10	0	-10	-20	-30	-40	-50	σ = 0,50 $p_y(t)$, T_{min} [°C] 10	0	-10	-20	-30	-40	-50	σ = 0,25 $p_y(t)$, T_{min} [°C] 10	0	-10	-20	-30	-40	-50
235	JR	B	As-rolled	20	27	60	50	40	35	30	25	20	90	75	65	55	45	40	35	135	115	100	85	75	65	60
	J0	C		0	27	90	75	60	50	40	35	30	125	105	90	75	65	55	45	175	155	135	115	100	85	75
	J2	D		-20	27	125	105	90	75	60	50	40	170	145	125	105	90	75	65	200	200	175	155	135	115	100
275	JR	B	As-rolled	20	27	55	45	35	30	25	20	15	80	70	55	50	40	35	30	125	110	95	80	70	60	55
	J0	C		0	27	75	65	55	45	35	30	25	115	95	80	70	55	50	40	165	145	125	110	95	80	70
	J2	D		-20	27	110	95	75	65	55	45	35	155	130	115	95	80	70	55	200	190	165	145	125	110	95
	M,N	B,C	TMCP / Normalized	-20	40	135	110	95	75	65	55	45	180	155	130	115	95	80	70	200	200	190	165	145	125	110
	ML,NL	C,D		-50	27	185	160	135	110	95	75	65	200	200	180	155	130	115	95	230	200	200	200	190	165	145
345, 350, 355	JR	B	As-rolled	20	27	40	35	25	20	15	15	10	65	55	45	40	30	25	25	110	95	80	70	60	55	45
	J0	C		0	27	60	50	40	35	25	20	15	95	80	65	55	45	40	30	150	130	110	95	80	70	60
	J2	D		-20	27	90	75	60	50	40	35	25	135	110	95	80	65	55	45	200	175	150	130	110	95	80
	K2,M,N	B,C	TMCP / Normalized	-20	40	110	90	75	60	50	40	35	155	135	110	95	80	65	55	200	200	175	150	130	110	95
	ML,NL	C,D		-50	27	155	130	110	90	75	60	50	200	180	155	135	110	95	80	210	200	200	200	175	150	130
420	M,N	B,C	TMCP / Normalized	-20	40	95	80	65	55	45	35	30	140	120	100	85	70	60	50	200	185	160	140	120	100	85
	ML,NL	C,D		-50	27	135	115	95	80	65	55	45	190	165	140	120	100	85	70	200	200	200	185	160	140	120
460	Q	B,C	QT	-20	30	70	60	50	40	30	25	20	110	95	75	65	55	45	35	175	155	130	115	95	80	70
	M,N	B,C	TMCP	-20	40	90	70	60	50	40	30	25	130	110	95	75	65	55	45	200	175	155	130	115	95	80
	QL	C,D	QT	-40	30	105	90	70	60	50	40	30	155	130	110	95	75	65	55	200	200	175	155	130	115	95
	ML,NL	C,D	TMCP	-50	27	125	105	90	70	60	50	40	180	155	130	110	95	75	65	200	200	200	175	155	130	115
	QL1	D,E	QT	-60	30	150	125	105	90	70	60	50	200	180	155	130	110	95	75	215	200	200	200	175	155	130
550	Q	B,C	QT	0	40	50	40	30	25	20	15	10	80	65	55	45	35	30	25	140	120	100	85	75	60	50
	Q	B,C		-20	30	60	50	40	30	25	20	15	95	80	65	55	45	35	30	165	140	120	100	85	75	60
	QL	C,D		-20	40	75	60	50	40	30	25	20	115	95	80	65	55	45	35	185	160	140	120	100	85	75
	QL	C,D		-40	30	90	75	60	50	40	30	25	135	115	95	80	65	55	45	200	185	160	140	120	100	85
	QL1	D,E		-40	40	110	90	75	60	50	40	30	160	135	115	95	80	65	55	200	200	185	160	140	120	100
	QL1	D,E		-60	30	130	110	90	75	60	50	40	185	160	135	115	95	80	65	200	200	200	185	160	140	120
690	Q	B,C	QT	0	40	40	30	25	20	15	10	10	65	55	45	35	30	20	20	120	100	85	75	60	50	45
	Q	B,C		-20	30	50	40	30	25	20	15	10	80	65	55	45	35	30	20	140	120	100	85	75	60	50
	QL	C,D		-20	40	60	50	40	30	25	20	15	95	80	65	55	45	35	30	165	140	120	100	85	75	60
	QL	C,D		-40	30	75	60	50	40	30	25	20	115	95	80	65	55	45	35	190	165	140	120	100	85	75
	QL1	D,E		-40	40	90	75	60	50	40	30	25	135	115	95	80	65	55	45	200	190	165	140	120	100	85
	QL1	D,E		-60	30	110	90	75	60	50	40	30	160	135	115	95	80	65	55	200	200	190	165	140	120	100

Notes:

1. Linear interpolation can be used in applying Table 3.7. Most applications require σ values between 0.75 $p_y(t)$ and 0.5 $p_y(t)$, and hence, σ= 0.25 $p_y(t)$ is given for interpolation purposes. Extrapolations beyond the extreme values are not valid.
2. Table 3.7 has been derived from guarantee values of Charpy impact energy in the direction of the rolling of the product.
3. Table 3.7 is also applicable for steel products supplied to other steel material specifications listed in Annex A1.1 with similar steel grades, i.e. having the same or similar minimum guaranteed values of Charpy impact energy.
4. TMCP denotes the manufacturing process of thermo-mechanically controlled process corresponding to BS EN 10025-4.
5. QT denotes the manufacturing process of quenching and tempering process corresponding to BS EN 10025-6.

3.3 BOLTS

3.3.1 Normal bolts

Bolts, nuts and washers shall comply with the requirements of the acceptable standards and references given in Annex A1.3.

Bolts with an ultimate tensile strength exceeding 1200 N/mm^2 should not be used unless test results demonstrate their acceptability in a particular design application.

3.3.2 High strength friction grip or preloaded bolts

High strength friction grip bolts, nuts and washers shall comply with the requirements of the reference standards given in Annex A1.3.

Requirements for the design of high strength friction grip bolted connections including tightening procedures are given in clause 9.3.

3.4 WELDING CONSUMABLES

All welding consumables shall conform to the requirements of the reference standards given in Annex A1.4. For steel with design strength not exceeding 690 N/mm^2 the specified yield strength, ultimate tensile strength, elongation at failure and Charpy impact value of the welding consumables shall be equal to or better than the corresponding values specified for the grade of steel being welded. The most onerous grade shall govern if dissimilar grades are welded together. For ultra-high strength steel, the welding consumables may, if necessary to produce a suitable joint, be of a lower strength; the elongation to failure and Charpy impact value should still match those of the parent material. In that case, the design strength of the weld must be based on the weld material.

3.5 STEEL CASTINGS AND FORGINGS

All steel castings and forgings shall comply with the requirements of the acceptable standards and references given in Annex A1.2.

3.6 MATERIALS FOR GROUTING OF BASEPLATES

Grout around foundation bolts and under column base plates should be one of the following forms:

Either a fluid Portland cement based grout comprising Portland cement and fine natural aggregate mixed in the ratio 1:1 by volume. The minimum amount of water is to be added to provide a viscosity suitable for the voids to be filled without bleeding or segregation of the fresh grout mix. The grout should be poured under a suitable head and tamped or vibrated to remove air pockets.

Or a proprietary non-shrink or resin based grout that does not contain high alumina cement.

3.7 MATERIALS FOR COMPOSITE CONSTRUCTION

Design for composite construction is covered in section 10. Materials used in composite construction other than steel are as follows:

3.7.1 Concrete

Concrete materials shall be in accordance with HKCC.

3.7.2 Reinforcement

Steel reinforcing bars and mesh materials shall be in accordance with HKCC.

3.7.3 Profiled steel sheets

Profiled steel sheets shall be in accordance with the requirements of the reference standards given in section 11.

3.7.4 Shear studs

Shear studs for composite construction shall be in accordance with the requirements of the reference standards given in Annex A1.6.

3.8 COLD-FORMED STEEL MATERIAL PROPERTIES

The material properties for cold formed steel open sections and sheet profiles as used in clauses 11.1 to 11.6 are given below. Acceptable references are given in Annex A1.7.

3.8.1 Mechanical properties

Both the yield strength (and hence the tensile strength) and the ductility of steel strips shall comply with the following:

3.8.1.1 Strength of steel

The design strength, p_y, is given by:

$$p_y = \frac{Y_s}{\gamma_{m1}} \leq \frac{U_s}{\gamma_{m2}} \qquad \text{when } Y_s < 460 \text{ N/mm}^2 \text{ for all steel thicknesses}$$

$$= \frac{Y_s}{\gamma_{m1}} \leq \frac{U_s}{\gamma_{m2}} \qquad \text{when } Y_s \geq 460 \text{ N/mm}^2 \text{ and } t > 1.0 \text{ mm} \qquad (3.5)$$

$$= \frac{Y_s}{\gamma_{m1}} \leq \frac{1.12U_s}{\gamma_{m2}} \qquad \text{when } Y_s \geq 460 \text{ N/mm}^2 \text{ and } t \leq 1.0 \text{ mm}$$

where

Y_s is the yield strength, R_{eH}

which is defined as the stress at the initiation of yielding for steel materials with clearly defined yield point; or

0.2% proof stress, $R_{p\,0.2}$, or the stress at 0.5% total elongation, $R_{t\,0.5}$ for steel materials with no clearly defined yield point, whichever is smaller. In case of dispute, 0.2% proof stress, $R_{p\,0.2}$, shall be adopted.

U_s is the minimum tensile strength, R_m .

γ_{m1} , γ_{m2} are the material factors given in Table 4.1.

Table 3.8 summaries the yield and the tensile strengths of common cold-formed steel strips. The design strength, p_y , may be increased in Class 1 and Class 2 steel due to cold forming as given in clause 11.2.2.1.

For steel conforming to acceptable reference standards, the values of R_{eH} , $R_{p\,0.2}$, $R_{t\,0.5}$ and R_m should normally be taken as specified in the relevant product standard for the steel sheet or strip used for the formed sections.

3.8.1.2 Ductility requirements

In general, the total elongation shall be not less than 10% for a 50 mm gauge length or 7% for a 200 mm gauge length standard specimen tested in accordance with CS2.

Alternatively, the following criteria on local and uniform elongation may be adopted:

(i) Local elongation in a 13 mm gauge length across the fracture should not be less than 20%.

(ii) Uniform elongation outside the fracture should not be less than 3%.

In this case, the use of steel materials should be limited to members under lateral loads primarily, such as decking, sheeting and purlins. Moreover, no increase in design strength due to cold forming should be allowed.

3.8.1.3 *High strength steel strips with limited ductility*

For high strength S550 steel strips that failed to comply with the ductility requirements listed in clause 3.8.1.2, the use of steel materials should be limited to members under lateral loads primarily, and the design yield strength should be reduced as follows:

p_y = 0.90 Y_s or 495 N/mm^2 (whichever is lesser) when $t \le 1.0$ mm
= 0.75 Y_s or 450 N/mm^2 (whichever is lesser) when $t \le 0.6$ mm

Moreover, no increase in design strength due to cold forming should be allowed.

Table 3.8 - Yield and tensile strengths for steels supplied in accordance with various national standards

Type of steel	**Grade**	**Yield strength Y_s (N/mm^2)**	**Tensile strength U_s (N/mm^2)**
British standard: BS EN 10025 Hot rolled steel sheet of structural quality	S235 S275 S355	235 275 355	360 430 510
British standard: BS EN 10147 Continuous hot dip zinc coated carbon steel sheet of structural quality	S220 G S250 G S280 G S320 G S350 G	220 250 280 320 350	300 330 360 390 420
British standard: BS EN 10149-2 & 3 High yield strength steels for cold forming	S315 MC S355 MC S420 MC S260 NC S315 NC S355 NC S420 NC	315 355 420 260 315 355 420	390 430 480 370 430 470 530
British standard: BS EN 10268 Cold-rolled steel flat products with high yield strength for cold forming – Technical delivery conditions	34/20 37/23 43/25 50/35 40/30 43/35 40F30 43F35	200 230 250 350 300 350 300 350	340 370 430 500 400 430 400 430
Australia standard: AS 1397 Steel sheet and strip	G250 G300 G350 G450 G500 G550	250 300 350 450 500 550	320 340 420 480 520 550
Chinese standard: GB 50018 Technical code of cold-formed thin-wall steel structures	Q235 Q345	205 300	- -

Table 3.8 - Yield and tensile strengths for steels supplied in accordance with various national standards (continued)

Type of steel	Grade	Yield strength Y_s (N/mm^2)	Tensile strength U_s (N/mm^2)
Japanese standard: JIS G 3302 Hot-Dip Zinc-Coated Steel Sheets and Coils	SGC340 SGC400 SGC440 SGC490 SGC570	245 295 335 365 560	340 400 440 490 570
Japanese standard: JIS G 3312 Prepainted Hot-Dip Zinc- Coated Steel Sheets and Coils	CGC340 CGC400 CGC440 CGC490 CGC570	245 295 335 365 560	340 400 440 490 570
Japanese standard: JIS G 3321 Hot-Dip 55 % Aluminium-Zinc Alloy-Coated Steel Sheets and Coils	SGLCC SGLC400 SGLC440 SGLC490 SGLC570	205 295 335 365 560	270 400 440 490 570
Japanese standard: JIS G 3322 Prepainted Hot-Dip 55 % Aluminium-Zinc Alloy-Coated Steel Sheets and Coils	CGLCC CGLC400 CGLC440 CGLC490 CGLC570	205 295 335 365 560	270 400 440 490 570
American standard: ASTM A308(M) Standard Specification for Steel Sheet, Terne (Lead-Tin Alloy) Coated by the Hot-Dip Process	Grade 170 Grade 205 Grade 230 Grade 275 Grade 550	170 205 230 275 550	290 310 330 360 565
American standard: ASTM A653(M) Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process	Grade 230 Grade 255 Grade 275 Grade 340 Grade 550	230 255 275 340 550	310 360 380 450 570
American standard: ASTM A792(M) Standard Specification for Steel Sheet, 55 % Aluminium-Zinc Alloy-Coated by the Hot-Dip Process	Grade 230 Grade 255 Grade 275 Grade 340 Grade 550	230 255 275 340 550	310 360 380 450 570