

Australian/New Zealand Standard™

Cold-formed steel structures



AS/NZS 4600:2018

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Australian/New Zealand Standard™

Cold-formed steel structures

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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee BD-082, Cold-formed Steel Structures. AS/NZS 4600:2005 will also remain current for 12 months after the date of publication of this Standard and after this time it will be superseded by AS/NZS 4600:2018. Regulatory authorities that reference this Standard in regulation may apply these requirements at a different time. Users of this Standard are advised to consult with these authorities to confirm their requirements.

The objective of this Standard is to provide designers of cold-formed steel structures with specifications for cold-formed steel structural members used for load-carrying purposes in buildings and other structures.

This edition incorporates the following major changes to the previous edition:

- (a) Inclusion of G500 and G550 steels in Clause 1.5.1.3 for steels where the effects of welding do not need to be tested.
- (b) Inclusion of reference to first order elastic, second order elastic and advanced analyses in Clause 1.6.2.
- (c) Earthquake design for Australia in Clause 1.6.4.1 based on structural ductility index and structural performance factor to align with latest edition of AS 1170.4.
- (d) Earthquake design for New Zealand in Clause 1.6.4.2 allows structural ductility factors up to 6.
- (e) Non-circular holes added to uniformly compressed stiffened elements in Clause 2.2.2.
- (f) New Clause 2.2.5 on intermittent connections in uniformly compressed elements.
- (g) Elastic buckling moments in Clause 3.3 moved to Paragraph D2.1, Appendix D, for members subject to bending.
- (h) Elastic buckling stresses in Clause 3.4 moved to Paragraph D1.1, Appendix D, for concentrically loaded compression members.
- (i) New Clause 3.7 for sections subject to combined bending and torsional loading.
- (j) New Clause 4.1.2 for compression members composed of two sections in contact.
- (k) Old Clause 4.3.3.3 for bracing of cleatless roof systems under gravity load deleted.
- (l) Revised Clause 4.3.3.3 (old Clause 4.3.3.4) for neither flange connected to sheeting has improved equations and a new diagram.
- (m) New equation for net section tension in Clause 5.3.3 has improved shear lag factor.
- (n) Bolted connections in bearing in Clause 5.3.4 now includes oversize and short-slotted holes.
- (o) Screws in shear and tension now allow the limit state based on testing of the screws.
- (p) Screwed connections in tension in Clause 5.4.3.2 now include round head, hex head, pancake screw washer head, hex washer head and domed head.
- (q) New rules in Clause 5.4.3.2 for screwed connections attaching roof battens.
- (r) New rules for screwed connections in combined bending and tension.
- (s) Design of power-actuated fasteners (PAFs) now included in Clause 5.5.
- (t) Revised equations for block shear rupture in Clause 5.7.3 based on active shear planes.

- (u) Range of prequalified members in Clause 7.1.1 (Table 7.1) for the direct strength method (DSM) extended to a wider range of sections with multiple intermediate stiffeners and return lips.
- (v) Compression and flexural members with holes and flexural members with inelastic reserve capacity now included in the DSM Clauses 7.2.1 and 7.2.2.
- (w) Shear and combined bending and shear added to the DSM in Clause 7.2.3.
- (x) Combined compression/tension and bending added to the DSM in Clause 7.2.4.5 respectively.
- (y) Design values based on prototype testing in Clause 8.4.1 can now use the average test value.
- (z) Strength prediction model from testing based on verification model BV1 of National Construction Code (NCC).
- (aa) New Section 9, Fire design, added for steel sections made from AS 1397, steel and with a fire resistant barrier.
- (bb) New Appendix B, Paragraph B2, First order elastic analysis, Paragraph B3, Second order elastic analysis and Paragraph B4, Advanced analysis, added.
- (cc) Appendix D extended to buckling stresses and actions for sections in compression, bending and shear including sections with holes.
- (dd) Informative Appendix G added for members subject to non-uniform temperature distribution.

Notes to the text contain information and guidance. They are not an integral part of the Standard.

Sections of this Standard have been reproduced from AISI S100, *North American Specification for the Design of Cold-Formed Steel Structural Members*, with permission from the American Iron and Steel Institute.

Standards Australia thanks NASH (National Association of Steel-framed Housing) for permission to reproduce sections of NASH Standard—*Residential and Low-rise Steel Framing, Part 1: Design Criteria* in Clause 1.6 and Clause 8.4 of this Standard.

A statement expressed in mandatory terms in a note to a table is deemed to be a requirement of this Standard.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the appendix to which they apply. A ‘normative’ appendix is an integral part of a Standard, whereas an ‘informative’ appendix is only for information and guidance.

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STANDARDS AUSTRALIA/STANDARDS NEW ZEALAND

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SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard sets out minimum requirements for the design of structural members cold-formed to shape from carbon or low-alloy steel sheet, strip, plate or bar not more than 25 mm in thickness and used for load-carrying purposes in buildings. It is also applicable for structures other than buildings, provided appropriate allowances are made for dynamic effects.

This Standard does not apply to the design of structures subject to brittle fracture.

1.2 NORMATIVE REFERENCES

Normative documents referenced in this Standard are listed in Appendix A.

NOTE: Documents referenced for informative purposes are listed in the Bibliography.

1.3 DEFINITIONS

For the purpose of this Standard, the definitions below apply. Definitions peculiar to a particular clause or section are also given in that clause or section.

1.3.1 Action

Set of concentrated or distributed forces acting on a structure (direct action), or deformation imposed on a structure or constrained within it (indirect action).

1.3.2 Action effect (internal effects of actions, load effects)

Internal forces and bending moments due to actions (stress resultants).

1.3.3 Arched compression element

A circular or parabolic arch-shaped compression element having an inside radius-to-thickness ratio greater than 8, stiffened at both ends by edge stiffeners. See Figure 1.3(C).

1.3.4 Assemblage of elements

A system of interconnected cold-formed steel elements that act together to resist earthquake action in such a way that the strength and deformation capacity of the system is not adversely affected by the buckling or crippling of any one element of the assemblage.

1.3.5 Bend

Portion adjacent to flat elements and having a maximum inside radius-to-thickness ratio (r_i/t) of 8. See Figure 1.3(A).

1.3.6 Braced member

Member for which the transverse displacement of one end of the member relative to the other is effectively prevented.

1.3.7 Can

Implies a capability or possibility and refers to the ability of the user of the Standard, or to a possibility that is available or that might occur.

1.3.8 Capacity design principles

Appropriate material Standard design and detailing provisions, which enable zones where post-elastic response is acceptable to be identified and detailed in a manner that ensures these zones are capable of accepting the inelastic demands placed upon them.

NOTE: All other zones are to be designed to ensure that all other undesirable inelastic response mechanisms are suppressed and detailed in a manner that the ultimate limit state horizontal deformations that they are expected to be subjected to, can be sustained without significant (e.g. greater than 20%) loss of load-carrying capacity after four complete cycles of loading.

1.3.9 Capacity reduction factor

A factor used to multiply the nominal capacity to obtain the design capacity.

1.3.10 Clinching

Structural fastening of two or more flat elements by single-point embossing or piercing without using additional material.

1.3.11 Cold-formed steel structural members

Shapes that are manufactured by press-braking blanks sheared from sheets, cut lengths of coils or plates, or by roll forming cold- or hot-rolled coils or sheets; both forming operations being performed at ambient room temperature, that is, without manifest addition of heat as required for hot-forming.

1.3.12 Direct strength method

An alternative design method that provides predictions of member resistance without the use of effective widths.

1.3.13 Design action effect

The action effect computed from the design values of the actions or design loads.

1.3.14 Design capacity

The product of the capacity reduction factor and the nominal capacity.

1.3.15 Distortional buckling

A mode of buckling involving change in cross-sectional shape, excluding local buckling.

1.3.16 Doubly-symmetric section

A section symmetric about two orthogonal axes through its centroid. See Figure 1.3(E).

1.3.17 Effective design width (or effective width)

Where the flat width of an element is reduced for design purposes.

1.3.18 Elements

Simple shapes into which a cold-formed structural member is considered divided and may consist of the following shapes:

- (a) *Flat elements* Appearing in cross-section as rectangles. See Figure 1.3(B).
- (b) *Bends* Appearing in cross-section as sectors of circular rings, having the inside radius-to-thickness ratio less than or equal to eight ($r_i/t \leq 8$). See Figure 1.3(B).
- (c) *Arched elements* Circular or parabolic elements having the inside radius-to-thickness ratio greater than eight ($r_i/t > 8$). See Figure 1.3(B).

1.3.19 Feed width (w_f)

Width of coiled or flat steel used in the production of a cold-formed product.

1.3.20 Flexural-torsional buckling

A mode of buckling in which compression members can bend and twist simultaneously without change of cross-sectional shape.

1.3.21 Length (of a compression member)

The actual length (l) of an axially loaded compression member, taken as the length centre-to-centre of intersections with supporting members, or the cantilevered length in the case of a freestanding member.

1.3.22 Limit states

States beyond which the structure no longer satisfies the design criteria.

NOTE: Limit states separate desired states (conformance) from undesired states (non-conformance).

1.3.23 Limit states, serviceability

States that correspond to conditions beyond which specified service criteria for a structure or structural element are no longer met.

1.3.24 Limit states, stability

States that correspond to the loss of static equilibrium of a structure considered as a rigid body.

1.3.25 Limit states, ultimate

States associated with collapse, or with other similar forms of structural failure.

NOTE: This generally corresponds to the maximum load-carrying resistance of a structure or structural element, but, in some cases, to the maximum applicable strain or deformation.

1.3.26 Load

The value of a force appropriate for an action.

1.3.27 Local buckling

A mode of buckling involving plate flexure alone without transverse deformation of the line or lines of intersection of adjoining plates.

1.3.28 May

Indicates the existence of an option.

1.3.29 Multiple-stiffened element

An element that is stiffened between webs, or between a web and a stiffened edge, by means of intermediate stiffeners that are parallel to the direction of stress. See Figure 1.3(C).

1.3.30 Nominal action effect or nominal load

An unfactored action effect or load determined in accordance with the relevant loading Standard.

1.3.31 Nominal capacity

The capacity of a member or connection, calculated using the parameters specified in this Standard.

1.3.32 Nominal dimension

A specified manufactured dimension.

1.3.33 Patterned hole

A hole of a fixed size that repeats at a regular interval.

1.3.34 Point-symmetric section

A section symmetrical about a point (centroid) such as a Z-section having equal flanges. See Figure 1.3(E)(b).

1.3.35 Power-actuated fastener (PAF)

Hardened steel fastener driven through a steel member into embedment material using either a power cartridge or compressed gas as the energy driving source.

1.3.36 Power-actuated fastener point

Portion of pointed end of PAF shank with varying diameter.

1.3.37 Primary structure

The structural system provided to carry the earthquake forces generated in the structure to the ground.

1.3.38 Proof testing

Application of test loads to a structure, sub-structure, member or connection, to ascertain the structural characteristics of only that one item under test.

1.3.39 Prototype testing

Application of test loads to one or more structures, sub-structures, members or connections, to ascertain the structural characteristics of that class of structures, sub-structures, members or connections which are nominally identical to the units tested.

1.3.40 Pull-over (pull-through)

Failure of a single-point connection by the sheet being pulled over the head of the fastener or the head of the fastener being pulled through the sheet.

1.3.41 Pull-out

Failure of a single-point connection by the embedded part of the fastener being pulled out of the member.

1.3.42 Rational elastic buckling analysis

An elastic buckling analysis in which the methodology is based on structural stability theory for the section or member as appropriate.

1.3.43 Segment (in a member subjected to bending)

The length between adjacent cross-sections, which are fully or partially restrained, or the length between an unrestrained end and the adjacent cross-section, which is fully or partially restrained.

1.3.44 Shall

Indicates that a statement is mandatory.

1.3.45 Should

Indicates a recommendation (non-mandatory).

1.3.46 Single-point fastener

A mechanical connection at a single discrete point such as a screw or rivet.

1.3.47 Singly-symmetric (monosymmetric) section

A section symmetric about only one axis through its centroid. See Figure 1.3(E)(c).

1.3.48 Special study

A procedure for the analysis or design, or both, of the structure, agreed between the authority having statutory powers to control the design and erection of a structure, and the design engineer.

1.3.49 Stiffened or partially stiffened compression element

A flat compression element (that is a plane compression flange of a flexural member or a plane web or flange of a compression member) of which both edges parallel to the direction of stress are stiffened by a web, flange, edge stiffener, intermediate stiffener, or the like. See Figure 1.3(a).

1.3.50 Stiffeners

1.3.50.1 Edge stiffener

Formed element at the edge of a flat compression element. See Figure 1.3(D)(a).

1.3.50.2 Intermediate stiffeners

Formed elements, employed in multiple-stiffened segments, and located between edges of stiffened elements. See Figure 1.3(D)(b).

1.3.51 Structural ductility factor

A numerical assessment of the ability of a structure to sustain cyclic inelastic displacements.

1.3.52 Structural performance factor

A numerical assessment of the ability of a building to survive cyclic displacements.

1.3.53 Structural response factor

The level of force reduction available for a given system compared with an elastic structural system.

1.3.54 Sub-element

The portion between adjacent stiffeners, or between web and intermediate stiffener, or between edge and stiffener.

1.3.55 Tensile strength

The minimum ultimate strength in tension specified for the grade of steel in the appropriate Standard.

1.3.56 Thickness

The base steel thickness (t), exclusive of coatings.

1.3.57 Unformed steel

Steel as received from the steel producer or warehouse before being cold-worked as a result of fabricating operations.

1.3.58 Unformed steel properties

Mechanical properties of unformed steel, such as yield stress, tensile strength and ductility.

1.3.59 Unstiffened compression element

A flat compression element which is stiffened at only one edge parallel to the direction of stress. See Figure 1.3(C)(b).

1.3.60 Yield stress

The minimum yield stress in tension specified for the grade of steel in the appropriate Standard.

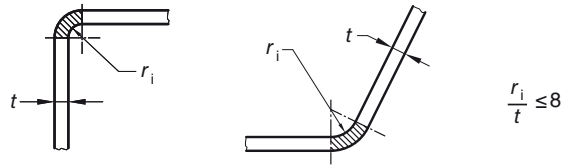
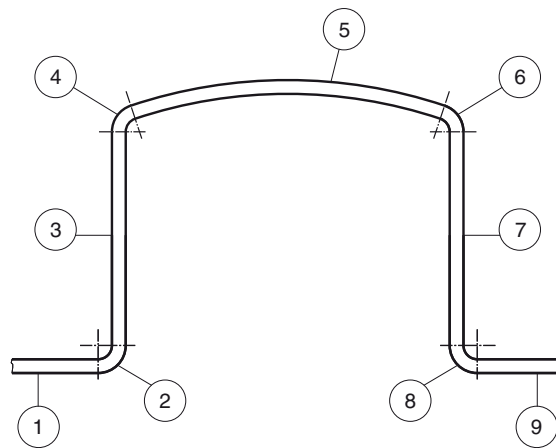


FIGURE 1.3(A) BENDS



NOTE: The member illustrated consists of the following nine elements:

- (a) Elements 1, 3, 7, 9 are flat elements (flats).
- (b) Elements 2, 4, 6, 8 are bends ($r_i/t \leq 8$).
- (c) Element 5 is an arched element ($r_i/t > 8$).

FIGURE 1.3(B) ELEMENTS

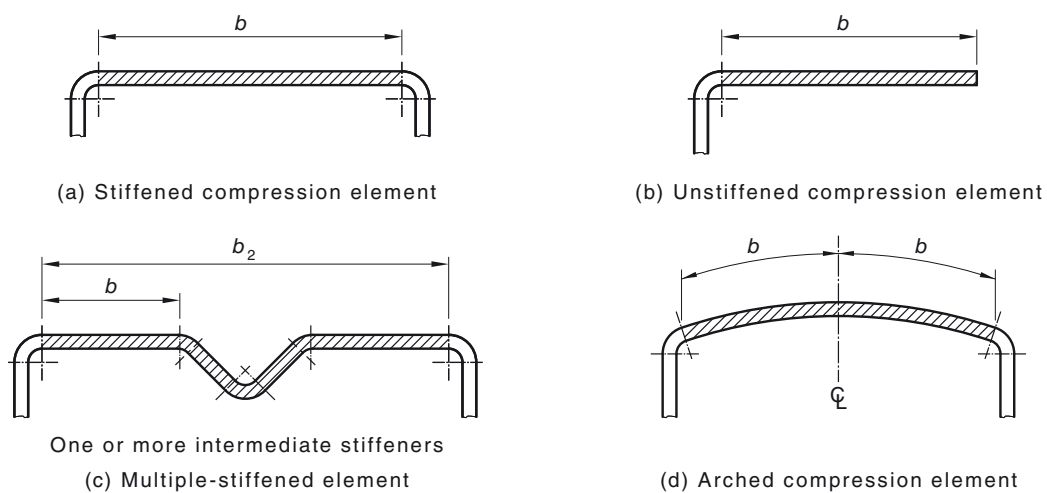


FIGURE 1.3(C) STIFFENING MODES

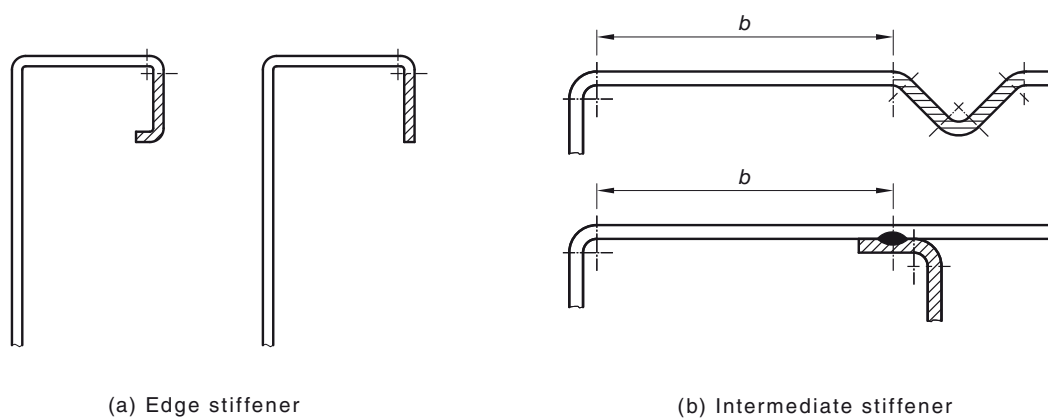


FIGURE 1.3(D) STIFFENERS

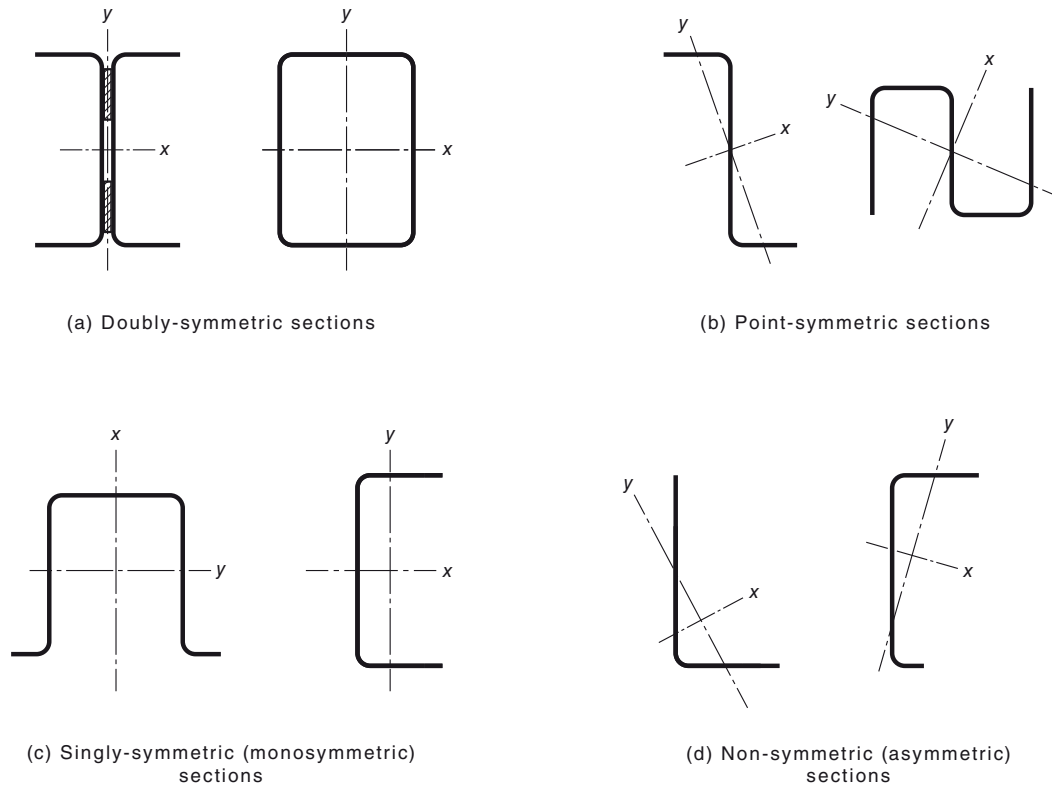


FIGURE 1.3(E) EXAMPLES OF SECTION SYMMETRY

1.4 NOTATION

The symbols used in this Standard are listed in Table 1.4.

Where non-dimensional ratios are involved, both the numerator and denominator are expressed in identical units.

The dimensional units for length and stress in all expressions or equations are to be taken as millimetres (mm) and megapascals (MPa) respectively, unless specifically noted otherwise.

An asterisk placed after a symbol denotes a design action effect due to the design load for the ultimate limit state.

TABLE 1.4
NOTATION

Symbol	Description	Reference
A_{av}	active shear area subject to shear in block shear rupture	5.7.3
A_e	minor diameter area of a bolt	5.3.5.1
A_e	effective area of the bearing stiffener subjected to uniform compressive stress; <i>or</i> effective area at the yield stress (f_y) to calculate N_s ; <i>or</i> effective area at the critical stress (f_n) to calculate N_c	3.3.8.2, 3.4.1, 3.6.3
A_g	gross area of the element including stiffeners; <i>or</i> gross area of the cross-section	2.6.1, 3.2.2
A_n	net area of the cross-section; <i>or</i> net area of the connected part	3.2.2, 5.3.3, 5.4.2.2, 5.5.2.2
A_{nt}	net area subject to tension in block shear rupture	5.6.3
A_o	reduced area due to local buckling; <i>or</i> plain shank area of a bolt	3.6.3, 5.3.5.1
A_s	reduced area of a stiffener; <i>or</i> gross area of the stiffener; <i>or</i> cross-sectional area of a transverse stiffener; <i>or</i> tensile stress area of a bolt	2.5.2, 2.6.2.1, 3.3.8.1, 5.3.5.2
A_{se}	effective area of a stiffener	2.4.2, 2.5.2
A_{st}	gross area of a shear stiffener	3.3.8.3
A_{s1}, A_{s2}	area of a member in compression consisting of the transverse stiffeners and a portion of the web	3.3.8.1
A_{wn}	net area of the web	5.7.1
a	bracing interval; <i>or</i> shear panel length for unstiffened web elements; <i>or</i> distance between transverse stiffeners for stiffened web elements; <i>or</i> distance between centre-lines of braces	3.3.4.1, 3.3.8.3, 4.3.3.3, Paragraph D2.1.1, Appendix D
B_c	constant	1.5.1.2
b	flat width of element excluding radii; <i>or</i> length of the web hole; <i>or</i> half the length of the arched compression element	2.2.1.2, 2.2.4.1, 2.5.2, 3.3.5, 4.1.2
b_e	effective width of uniformly compressed stiffened and unstiffened elements used for determining the capacity	2.2.1.2, 2.2.2.2, 2.2.3.2, 2.3.1.2, 2.3.1.3, 2.3.2.2, 2.3.2.3, 2.4.2, 2.4.3, 2.5.3, 2.6.1, 2.6.2.2, 2.7
b_{ed}	effective width of uniformly compressed stiffened and unstiffened elements used for determining the deflection	2.2.1.3, 2.2.2.3
b_{e1}, b_{e2}	effective width of stiffened element with stress gradient	2.2.3.2, 2.2.3.3
b_f	flange width of a section	3.4.3
b_o	total flat width of an element with an intermediate stiffener	2.6.1, 2.6.2.1
b_p	greatest sub-element flat width	2.6.3.1

(continued)

TABLE 1.4 (continued)

Symbol	Description	Reference
b_1	width of the flange projecting beyond the web for I-beams and similar sections; <i>or</i> half the distance between webs for box- or U-type sections; <i>or</i> sum of the flange projection beyond the web and the depth of the lip for I-beams and similar sections; <i>or</i> width of stiffened element	2.1.3.2, 2.1.3.3, 2.3.2.2
b_2	width of unstiffened element; <i>or</i> flat width of element with intermediate stiffener excluding radii; <i>or</i> total flat width of the edge-stiffened element	2.3.2.2, 2.5.2, 2.7
C	for compression members, ratio of the total bend cross-sectional area to the total cross-sectional area of the full section; <i>and</i> for flexural members, ratio of the total bend cross-sectional area of the controlling flange to the full cross-sectional area of the controlling flange; <i>or</i> coefficient; <i>or</i> bearing factor	1.5.1.2, 3.3.6.2, 5.3.4.2, 5.4.2.3
C_b	coefficient depending on moment distribution in the laterally unbraced segment	Paragraph D2.1.1, Appendix D
C_i	horizontal distance from the edge of the element to the centre-line of the stiffener	2.6.3.1
C_{TF}	coefficient for unequal end moment	3.5.1, Paragraph D2.1.1, Appendix D
C_l	coefficient of bearing length	3.3.6.2
C_{mx}, C_{my}	coefficient for unequal end moment	3.5.1
C_r	coefficient of inside bent radius	3.3.6.2
C_s	coefficient for moment causing compression or tension on the shear centre side of the centroid	3.3.3.2.1
C_w	coefficient of web slenderness	3.3.6.2
C_y	compression strain factor	3.3.2.3
c	flat width	2.2.2.2.2
c_f	amount of curling	2.1.3.2
d	depth of a section (or actual stiffener dimension)	2.1.3.2, Figure 2.4.2(a), 3.3.6.3, 3.4.3
d_a	average diameter of an arc spot weld at mid-thickness of t_c ; <i>or</i> average width of an arc seam weld	5.2.4.2, 5.2.5.2
d_e	effective diameter of a fused area of an arc spot weld; <i>or</i> effective width of an arc seam weld at fused surfaces	5.2.4.1, 5.2.4.2, 5.2.5.2
d_f	nominal diameter of a bolt, screw, blind rivet	Table 5.3.1, 5.3.2, 5.3.4.2, 5.4.1, 5.4.2.1, 5.4.2.2, 5.4.2.3, 5.5.1, 5.5.2.1, 5.5.2.2, 5.5.2.3
d_h	diameter of a hole	2.2.2.2, Table 5.3.1, 5.3.2, 5.6.1
d_l	overall stiffener dimension (or overall depth of lip)	Figure 2.4.2(a)
d_o	outside diameter of a tubular member	3.6.1, 3.6.2
d_s	reduced effective width of a stiffener	Figure 2.4.2(b)

(continued)

TABLE 1.4 (continued)

Symbol	Description	Reference
d_{se}	effective width of a stiffener	Figure 2.4.2(b)
d_{sh}	nominal shank diameter	Figure F1, Appendix F
d_w	depth of the compressed portion of the web; <i>or</i> visible diameter of the outer surface of an arc spot weld; <i>or</i> width of an arc seam weld; <i>or</i> screw head or washer diameter	3.3.2.3, 5.2.4.2, 5.2.5.2, 5.4.3.2
d_{wc}	coped depth of a web	5.7.1
d_{wh}	depth of the web hole	2.2.4.1, 3.3.4.2
d_1	depth of the flat portion of a web measured along the plane of the web; <i>or</i> width of elements adjoining the stiffened element	2.1.3.4, 2.2.4.1, 2.6.1, 3.3.4.1, 3.3.4.2, 3.3.6.2
E	Young's modulus of elasticity (200×10^3 MPa)	2.2.1.2, 3.3.2.3, 5.2.4.2
e	edge distance measured in the line of the force from centre-line of an arc spot weld, arc seam weld or from centre of a bolt hole to the nearest edge of an adjacent weld or bolt hole, or to the end of the connected part toward which the force is directed; <i>or</i> distance measured in the line of force from the centre of a standard hole to the nearest end of the connected part	5.2.4.3, 5.2.5.3, 5.3.2, 5.4.2.4, 5.5.2.4
e_y	yield strain	3.3.2.3
$f_{bending}$	bending stress at location in cross-section where combined bending and torsion stress effect is maximum	3.7
$f_{bending\ max}$	bending stress at extreme fibre taken on the same side of the neutral axis as $f_{bending}$	3.7
f_c	stress at service load in the cover plate or sheet; <i>or</i> fatigue strength corrected for thickness of material	4.1.2, 6.1.3
f_{cr}	plate elastic buckling stress	2.2.1.2, 3.4.2
f_t	uncorrected fatigue strength	6.1.3
f_n	critical stress	3.3.8.1, 3.4.1, 3.6.3
f_{oc}	elastic flexural, torsional and flexural-torsional buckling stress	3.4.1, 3.6.3, Paragraph D1.1.1.1, Appendix D
f_{od}	elastic distortional buckling stress of the cross-section	3.3.3.3, 7.2.1.4, 7.2.2.4.2, Paragraphs D1.2, D2.2, Appendix D
f_{ol}	elastic local buckling stress	7.2.1.3.1, 7.2.2.3.2
f_{ox}	elastic buckling stress in an axially loaded compression member for flexural buckling about the x -axis	Paragraph D1.1.1.2, Appendix D
f_{oy}	elastic buckling stress in an axially loaded compression member for flexural buckling about the y -axis	Paragraph D1.1.1.2, Appendix D
f_{oz}	elastic buckling stress in an axially loaded compression member for torsional buckling	Paragraph D1.1.1.2, Appendix D
f_{rn}	detail category reference fatigue strength at n_r -normal stress	6.1.3
f_{rne}	corrected detail category reference fatigue strength for normal stress	6.1.3
f_{rs}	detail category reference fatigue strength at n_r -shear stress	6.1.3
f_{rsc}	corrected detail category reference fatigue strength for shear stress	6.1.3
$f_{torsion}$	torsional stress at location in cross-section where combined bending and torsion stress effect is maximum	3.7

(continued)

TABLE 1.4 (continued)

Symbol	Description	Reference
f_u	tensile strength used in design; <i>or</i> tensile strength of sheet	1.5.1.1, 1.5.1.4, 1.5.1.6, 1.5.2, 3.2.2, 5.3.4.2
f_{uf}	minimum tensile strength of a bolt	5.3.5.1
f_{uv}	tensile strength of unformed steel	1.5.1.2
f_{uw}	nominal tensile strength of a weld metal	5.2.2.2, 5.2.3.4
f_{ul}	tensile strength used in the design of the connected plate of the thickness t_1 ; <i>or</i> tensile strength of the sheet in contact with the screw head or with the rivet head	5.2.3.3, 5.4.2.3, 5.5.2.3
f_{u2}	tensile strength used in the design of the connected plate of the thickness t_2 ; <i>or</i> tensile strength of the sheet not in contact with the screw head or with the rivet head	5.2.3.3, 5.4.2.3, 5.5.2.3
f_y	yield stress used in design; <i>or</i> yield stress of web steel; <i>or</i> yield stress of stiffener; <i>or</i> yield stress used in design for the lower strength base steel; <i>or</i> tensile or compressive yield stress	1.5.1.1, 1.5.1.4, 1.5.1.6, 1.5.2, 3.2.2, 3.3.2.3, 3.3.8.2, 5.2.2.1, 6.1.3, 8.1.3
f_{wy}	lower yield stress value of the beam web (f_y) or of the stiffener section (f_{ys})	3.3.8.1
f_{ya}	average design yield stress of a full section	1.5.1.2
f_{yc}	tensile yield stress of bends	1.5.1.2
f_{yf}	yield stress of flat portions; <i>or</i> yield stress of unformed steel if tests are not made; <i>or</i> yield stress of flat coupons of formed members	1.5.1.2, 8.1.4.1
f_{ys}	yield stress of stiffener steel	3.3.8.1
f_{yv}	tensile yield stress of unformed steel	1.5.1.2
f_3	detail category fatigue strength at constant amplitude fatigue limit (5×10^6 cycles)	6.1.3
f_{3c}	corrected detail category fatigue strength at constant amplitude fatigue limit	6.1.3
f_5	detail category fatigue strength at cut off limit (108 cycles)	6.1.3
f_{5c}	corrected detail category fatigue strength at cut off limit	6.1.3
f^*	design stress in the compression element calculated on the basis of the effective design width; <i>or</i> design stress range	2.2.1.2, 2.4.2, 6.1.3
f_{av}^*	average design stress in the full, unreduced flange width	2.1.3.2
f_d^*	design compressive stress in the element being considered, based on the effective section at the load for which deflections are determined	2.2.1.3, 2.2.2.3, 2.6.2.2, 2.6.3.2
f_{d1}^*	calculated stress f_1^*	2.2.3.3
f_{d2}^*	calculated stress f_2^*	2.2.3.3
f_i^*	design stress range for loading event i	6.1.3
f_1^*, f_2^*	web stresses calculated on the basis of the effective section specified in Clause 2.2.3.2 or the full section specified in Appendix F	2.2.3.2, 2.3.2.2
G	shear modulus of elasticity (80×10^3 MPa)	Paragraph D1.1.1.2, Appendix D

(continued)

TABLE 1.4 (continued)

Symbol	Description	Reference
I_a	adequate second moment of area of a stiffener, so that each component element behaves as a stiffened element	2.4.2, 2.5.2
I_b	second moment of area of the full, unreduced cross-section about the bending axis	3.5.1
I_{eff}	effective second moment of area for deflection	7.1.3
I_g	gross second moment of area	7.1.3
$I_{min.}$	minimum second moment of area	2.8
I_s	second moment of area of a full stiffener about its own centroidal axis parallel to the element to be stiffened	2.4.2, 2.5.2
I_{sp}	second moment of area of a stiffener about the centre-line of the flat portion of the element	2.6.2.1
I_w	warping constant for a cross-section	Paragraphs D1.1.1.2, Appendix D, and E1, Appendix E
I_x, I_y	second moment of area of the cross-section about the principal x- and y-axes	Paragraph D2.1.1, Appendix D
I_x	second moment of area of the cross-section about its centroidal axis perpendicular to the web	4.3.3.3
I_{xy}	product of second moment of area of the full section about its centroidal axes parallel and perpendicular to the web	4.3.3.3
I_{yc}	second moment of area of the compression portion of a section about the centroidal axis of the full section parallel to the web, using the full unreduced section	Paragraph D2.1.1, Appendix D
i	index for stiffener 'i'	2.6.3.1
J	torsion constant for a cross-section	Paragraphs D2.1.1, Appendix D, and E1, Appendix E
k	plate buckling coefficient; <i>or</i> non-dimensional yield stress	2.2.1.2, 2.3.2.2, Table 2.4.2, 2.5.2, 2.6.1
k_d	plate buckling coefficient for distortional buckling	2.6.1
k_f	factor to account for variation due to fabrication	8.4.2.1
k_{loc}	plate buckling coefficient for local sub-element buckling	2.6.1
k_m	factor to account for variation due to material	8.4.2.1
k_s	shear stiffener coefficient	3.3.8.3
k_{st}	stiffener type coefficient	3.3.8.2
k_t	correction factor for distribution of forces; <i>or</i> factor to account for accuracy of the prediction	3.2.2, Table 3.2
k_{t-ave}	sampling factor	8.4.1
k_{t-min}	sampling factor	8.4.1
k_v	shear buckling coefficient	3.3.4.1, 3.3.8.3
L_{crd}	distortional buckling half-wavelength with gross cross section	Paragraph D1.2.2, Appendix D
L_{gv}	distance from free edge to centre-line of bolt furthest from the edge	5.7.3
L_h	overall length of hole	2.2.2.2.2

(continued)

TABLE 1.4 (continued)

Symbol	Description	Reference
l	actual length of a compression member; <i>or</i> full span for simple beams; <i>or</i> distance between inflection points for continuous beams; <i>or</i> twice the length of cantilever beams; <i>or</i> unbraced length of a member; <i>or</i> laterally unbraced length of a member; <i>or</i> length of a member	1.3.21, 2.1.3.3, 3.3.3.2.2, 3.5.1, 4.1.1, 6.1.3, Paragraph D2.1.1, Appendix D
l_a	lap length	Figure F1, Appendix F
l_b	actual length of bearing	3.3.6.2, 3.3.6.3
l_{br}	unsupported length of bracing or other restraint that restricts distortional buckling of the element	2.6.2.1
l_c	unclamped length of the specimen	Figure F1, Appendix F
l_e	effective length of the member	3.4.1, Paragraph D1.1.1.1, Appendix D
l_{ex}, l_{ey}, l_{ez}	effective buckling length for bending about the x - and y -axes, and for twisting, respectively	Paragraph D1.1.1.2
l_{eb}	effective length in the plane of bending	3.5.1
l_g	gauge length for measuring the joint displacement	Figure F1, Appendix F
l_{st}	length of transverse stiffener	3.3.8.1
l_{sb}	length of bearing stiffener	3.3.8.1
l_u	limit of unbraced length by which lateral-torsional buckling is not considered	3.3.3.2.2
l_w	length of the full size of the weld; <i>or</i> length of fillet weld	5.2.2.1, 5.2.3.3, 5.2.3.4, 5.2.5.2
l_{w1}, l_{w2}	leg lengths of fillet weld	5.2.3.4
M	moment due to nominal loads on member to be considered	7.1.4
M_b	nominal member moment capacity	2.2.1.2, 3.3.1, 3.3.3.1, 3.3.3.2.1, 3.3.3.2.2, 3.3.3.3, 3.3.3.4, 3.3.5, 3.6.2, 7.2.2.1 Paragraph B2, Appendix B
M_{bx}, M_{by}	nominal member moment capacities about the x - and y -axes, respectively	3.5.1, 3.5.2
M_c	critical moment	3.3.3.2.1, 3.3.3.3
M_{bd}	nominal member capacity for distortional buckling	7.2.2.4.2, 7.2.2.4.3
M_{be}	nominal member capacity for lateral-torsional buckling	7.2.2.2.2, 7.2.2.3.2
M_{bt}	nominal member capacity for local buckling	7.2.2.3.2, 7.2.2.3.3
$M_{max.}$	absolute value of the maximum moment in the unbraced segment	Paragraph D2.1.1, Appendix D
M_n	nominal flexural capacity	7.1.4
M_o	elastic buckling moment; <i>or</i> elastic lateral-torsional buckling moment	7.2.2.2.2, Paragraph D2.1.1, Appendix D
M_{od}	elastic buckling moment in the distortional mode	3.3.3.3, 7.2.2.4.2, Paragraph D2.2.4.2, Appendix D

(continued)

TABLE 1.4 (continued)

Symbol	Description	Reference
M_{ol}	elastic local buckling moment	7.2.2.3.2
M_s	nominal section moment capacity	2.2.1.2, 3.3.1, 3.3.2.1, 3.3.2.2, 3.3.2.3, 3.3.3.5, 3.3.5, 3.3.7
M_{sxf}, M_{syf}	nominal section yield moment capacity of the full section about the x - and y -axes, respectively	3.5.2
M_y	moment causing initial yield at the extreme compression fibre of a full section	2.2.1.2, 3.3.3.2.1, 3.3.3.3
M_{y-net}	member yield capacity on net cross-section	7.2.2.4.3
M_1	smaller bending moment at the ends of the unbraced length	Paragraph D2.1.1, Appendix D
M_2	larger bending moment at the ends of the unbraced length	Paragraph D2.1.1, Appendix D
M_3	absolute value of the moment at quarter point of the unbraced segment	Paragraph D2.1.1, Appendix D
M_4	absolute value of the moment at mid-point of the unbraced segment	Paragraph D2.1.1, Appendix D
M_5	absolute value of the moment at three-quarter point of the unbraced segment	Paragraph D2.1.1, Appendix D
M^*	design bending moment	3.3.1, 3.3.5, 3.3.7, 3.6.2
M_x^*, M_y^*	design bending moment about the x - and y -axes, respectively	3.5.1, 3.5.2
m	constant; <i>or</i> non-dimensional thickness; <i>or</i> distance from the shear centre of one channel to the mid-plane of its web; <i>or</i> distance from the concentrated load to the brace	1.5.1.2, 4.1.1, 4.3.3.3, Paragraph E1, Appendix E
N_c	nominal member capacity of a member in compression	2.2.1.3, 3.3.8.1, 3.4.1, 3.4.3, 3.5.1, 7.2.1.2.1
N_{cd}	nominal member capacity for distortional buckling	7.2.1.1, 7.2.1.4.1
N_{ce}	nominal member capacity for flexural, torsional or flexural-torsional buckling	7.2.1.1, 7.2.1.2.1
N_{cl}	nominal member capacity for local buckling	7.2.1.1, 7.2.1.3.1
N_e	elastic buckling load	3.5.1
N_f	nominal tensile capacity of the section of the connected part	5.3.3
N_{ft}	nominal tensile capacity of a bolt	5.3.5.2
N_{oc}	least of the elastic column buckling load in flexural, torsional and flexural-torsional buckling	7.2.1.2.1
N_{od}	elastic distortional compression member buckling load	7.2.1.4.1
N_{ol}	elastic local buckling load	7.2.1.3.1
N_{ou}	nominal pull-out capacity of a screw	5.4.3.2
N_{ov}	nominal pull-over (pull-through) capacity of a screw	5.4.3.2
N_s	nominal section capacity of a member in compression	2.2.1.2, 3.3.8.1, 3.4.1, 3.5.1
N_t	nominal section capacity of a member in tension; <i>or</i> nominal capacity of the connection in tension; <i>or</i> capacity of the net section of the connected part	3.2.1, 3.5.2, 5.4.2.2, 5.4.3.2, 5.6.2.2

(continued)

TABLE 1.4 (continued)

Symbol	Description	Reference
N_w	nominal tensile or compressive capacity of a butt weld or an arc spot weld	5.2.2.1, 5.2.4.4
N_y	nominal yield capacity of a member in compression	7.2.1.2
N^*	design axial force, tensile or compressive; <i>or</i> design concentrated load or reaction	3.2.1, 3.3.8.1, 3.4.1, 3.5.1, 3.5.2, 3.6.3, 4.1.1
N_f^*	design tensile force on the net section of the connected part	5.3.3
N_{ft}^*	design tensile force on a bolt	5.3.5.2, 5.3.5.3
N_t^*	design tensile force on the net section of a connected part using screws or blind rivets	5.4.2.2, 5.4.3.2, 5.5.2.2
N_w^*	design tensile or compressive force normal to the area of a butt weld or an arc spot weld	5.2.2.1, 5.2.4.4
n	exponent	2.5.2
n_h	number of holes in the critical plane	5.6.1
n_i	number of cycles of nominal loading event i , producing f_i^*	6.1.3
n_n	number of the shear planes with threads intercepting the shear plane	5.3.5.1
n_r	reference number of stress cycles (2×10^6 cycles)	6.1.3
n_{sc}	number of stress cycles	6.1.3
n_x	number of shear planes without threads intercepting the shear plane	5.3.5.1
q	intensity of the design load on a beam	4.1.1
R	modification factor for the distortional plate buckling coefficient; <i>or</i> reduction factor; <i>or</i> radius of outside bend surface	2.6.1, 3.3.3.4, 3.3.3.5, 3.6.3, 5.2.6.2
R_b	nominal capacity for concentrated load or reaction for one solid web connecting top and bottom flanges	3.3.6.1, 3.3.6.2, 3.3.7
R_d	design capacity	1.6.3, 8.4.1
$R_{min.}$	minimum value of the test results	8.2.3
R_n	nominal capacity for block shear rupture of the beam-end or tension member connection	5.7.3
R_u	nominal capacity	1.6.3
R_{wc}	web crippling capacity for channel-section flexural member	3.3.8.2
R^*	design concentrated load or reaction in the presence of bending moment	3.3.6.1, 3.3.7
R_b^*	design concentrated load or reaction	4.1.1
r	radius of gyration of the full, unreduced cross-section; <i>or</i> centre-line radius	4.1.2, Paragraph D1.1.1.2, Appendix D
r_f	ratio of the force transmitted by the bolts or screws, or rivets at the section considered, divided by the tensile force in the member at that section	5.4.2.2, 5.5.2.2
r_i	inside bend radius	1.5.1.2, 3.3.6.2
r_{ol}	polar radius of gyration of the cross-section about the shear centre	Paragraph D1.1.1.2, Appendix D
r_x, r_y	radii of gyration of the cross-section about the x - and y -axes, respectively	Paragraph D1.1.1.2, Appendix D

(continued)

TABLE 1.4 (continued)

Symbol	Description	Reference
r_1	radius of gyration of I-section about the axis perpendicular to the direction in which buckling occurs for the given conditions of end support and intermediate bracing	4.1.1
S	slenderness factor	2.4.2, 2.5.2, 2.7
S_e	elastic section modulus of the effective section calculated with extreme compression or tension fibre at f_y	3.3.3.5
S_f	spacing of bolts perpendicular to the line of the force, or the width of the sheet in the case of a single bolt	5.3.3
S_p	structural performance factor	1.6.4.2.4
S^*	design action effects (design actions)	5.6.3
s	fastener distance from the centre-line of the web divided by the flange width for Z-sections; flange width minus the fastener distance from the centre-line of the web divided by the flange width for channel-sections; spacing in line of the stress of welds, bolts, rivets connecting a cover plate, sheet or a non-integral stiffener in compression to another element; centre to centre hole spacing	2.2.2.2.2, 3.4.3, 4.1.3
s_{end}	clear distance from hole to end of section	2.2.2.2.2
s_f	spacing of bolts, screws or rivets perpendicular to the line of the force; <i>or</i> width of sheet, in the case of a single bolt, screw or rivet	5.3.3, 5.4.2.2, 5.5.2.2
s_g	vertical distance between two rows of connections nearest to the top and bottom flanges; <i>or</i> gauge, the distance measured at right angles to the direction of the design action in the member, centre-to-centre of holes in consecutive lines	4.1.1, 5.3.1
s_{max}	maximum longitudinal spacing of welds or other connectors joining two channels to form an I-section	4.1.1
S_{od}	imperfection multiplier for distortional buckling	Paragraph B4, Appendix B
S_{ol}	imperfection multiplier for local buckling	Paragraph B4, Appendix B
s_p	staggered pitch distance measured parallel to the direction of the design action in the member, centre-to-centre of holes in consecutive lines	5.3.1
t	nominal base steel thickness of any element or section exclusive of coatings; <i>or</i> thickness of the uniformly compressed stiffened elements; <i>or</i> base thickness of beam web; <i>or</i> thickness of a channel- or Z-section; <i>or</i> thickness of the cover plate or sheet; <i>or</i> thickness of the thinnest connected part; <i>or</i> thickness of element; <i>or</i> thickness of thinnest outside sheet; <i>or</i> thickness of the connected part; <i>or</i> thickness of the holed material; <i>or</i> thickness of the part in which the end distance is measured; <i>or</i> thickness of coped web	1.3.54, 2.1.3.1, 2.2.1.2, 2.6.1, 3.3.8.1, 3.4.3, 4.1.3, 5.2.4.3, 5.2.5.2, 5.2.7, 5.3.1, 5.3.2, 5.3.4.2, 5.4.2.4, 5.5.2.4, 5.7.1
t_c	total combined base steel thickness (exclusive of coatings) of sheets involved in shear transfer	5.2.4.2
t_f	thickness of the flange	2.1.3.2

(continued)

TABLE 1.4 (continued)

Symbol	Description	Reference
t_p	plate thickness	6.1.3
t_s	thickness of the stiffener	3.3.8.1
t_t	design throat thickness of a butt weld	5.2.2.1, 5.2.3.4, 5.2.6.2
t_w	thickness of a web	2.1.3.4, 3.3.4.1, 3.3.6.2, 3.3.7
t_1	thickness of the connecting plate of the tensile strength f_{u1} ; or thickness of the sheet in contact with the screw head or rivet head	5.2.3.3, 5.4.2.3, 5.5.2.3
t_2	thickness of the connecting plate of the tensile strength f_{u2} ; or thickness of the sheet not in contact with the screw head or rivet head	5.2.3.3, 5.4.2.3, 5.5.2.3
V_b	nominal bearing capacity of the connected part	5.3.4.2, 5.3.4.3, 5.4.2.3, 5.5.2.3
V_f	nominal shear capacity of the connected part along two parallel lines in the direction of the applied force	5.3.2
V_{fv}	nominal shear capacity of a bolt or screw	5.3.5.1, 5.4.2.1, 5.5.2.1
V_n	nominal shear capacity of an arc seam weld or of a beam-end connection	5.2.5.2, 5.7.1
V_{sc}	coefficient of variation of structural characteristic	8.3.1, Tables 8.4.1(A) and 8.4.1(B)
V_v	nominal shear capacity of the web	3.3.4.1, 3.3.4.2, 3.3.5, 7.2.3
V_w	nominal shear capacity of a butt, fillet, arc spot, flare or resistance weld; or nominal shear force transmitted by the weld	5.2.2.2, 5.2.3.1, 5.2.4.2, 5.2.4.3, 5.2.6.2, 5.2.7
V^*	design shear force	3.3.2.3, 3.3.4.1, 3.3.5
V_b^*	design bearing force on a screw or on a rivet; or design bearing force on the connected part	5.4.2.3, 5.5.2.3
V_f^*	design shear force of the connected part	5.3.2
V_{fv}^*	design shear force on a bolt, screw or rivet	5.3.5.1, 5.3.5.3, 5.4.2.4
V_n^*	design shear force on an arc seam weld or a beam-end connection	5.2.5.2, 5.7.1
V_w^*	design shear force on a butt, fillet, arc spot, flare or resistance weld	5.2.2.2, 5.2.3.1, 5.2.4.2, 5.2.4.3, 5.2.6.2, 5.2.7
w	width of the specimen	Figure F1, Appendix F
w_f	feed width of the coiled or flat sheet	1.3.19, Note 2 to Figure E1, Appendix E
x, y	principal axes of the cross-section	Paragraphs D1.1.1.2 and D2.1.1, Appendix D
x_o, y_o	coordinates of the shear centre of the cross-section	Paragraphs D1.1.1.2 and D2.1.1, Appendix D
Z_c	effective section modulus calculated at a stress f_c in the extreme compression fibre	3.3.3.3
Z_e	effective section modulus calculated with the extreme compression or tension fibre at f_y	3.3.3.2.1, 3.3.3.4, 3.3.3.5
Z_f	full unreduced section modulus for the extreme compression fibre	3.3.3.2.1, 3.3.3.3
Z_{fnet}	net section modulus referred to the extreme fibre at yield	7.2.2.3.3
Z_{ft}	section modulus of the full unreduced section for the extreme tension fibre about the appropriate axis	3.5.2

(continued)

TABLE 1.4 (continued)

Symbol	Description	Reference
α	modification factor for type of bearing connection	5.3.4.2
α_{nx}, α_{ny}	moment amplification factors	3.5.1
α_s	inverse of the slope of the S-N curve	6.1.3
β	coefficient	2.6.2.1
β_x, β_y	monosymmetry section constant about the x - and y -axes, respectively	Paragraphs D2.1.1, Appendix D, and E2, Appendix E
β_{tf}	thickness correction factor	6.1.3
γ	importance factor	2.6.2.1
δ	coefficient	2.6.2.1
θ	angle between the plane of the web and the plane of the bearing surface	3.3.6.2
$\lambda, \lambda_1, \lambda_2$	slenderness ratio	2.2.1.2, 3.3.2.3, 3.3.7
λ_b	non-dimensional slenderness used to determine M_c for members subject to lateral buckling	3.3.3.2.1
λ_c	non-dimensional slenderness used to determine f_n ; <i>or</i> non-dimensional slenderness used to determine N_{ce}	3.4.1, 3.6.3, 7.2.1.1
λ_d	non-dimensional slenderness used to determine M_c for members subject to distortional buckling; <i>or</i> non-dimensional slenderness used to determine N_{cd} and M_{bd}	3.3.3.3, 7.2.1.4.2, 7.2.2.4.2
$\lambda_{d1}, \lambda_{d2}$	limiting slenderness values	7.2.2.4.3
λ_l	non-dimensional slenderness used to determine N_{cl} ; <i>or</i> non-dimensional slenderness used to determine M_{bl}	7.2.1.3.1, 7.2.2.3.2
λ_v	non-dimensional slenderness used to determine V_v	7.2.3.2, 7.2.3.3
μ	structural ductility factor	1.6.4.2.2
ν	Poisson's ratio = 0.3	2.2.1.2
ϕ	capacity reduction factor; frame imperfection (out-of-plumb)	1.5.1.4, 5.2.2.1, 5.2.2.2, 5.2.3.1, 5.2.4.2, 5.2.4.3, 5.2.5.2, 5.2.6.2, 5.2.7, 5.3.2, 5.3.3, 5.3.5.1, 5.3.5.2, 5.4.2.2, 5.4.2.3, 5.5.2.2, 5.5.2.3, 5.5.2.4, 5.7.1, 5.7.3, 6.1.3 Paragraph B2, Appendix B
ϕ_b	capacity reduction factor for bending	3.3.1, 3.5.1, 7.2.2
ϕ_c	capacity reduction factor for compression	3.3.8.1, 3.4.1, 3.5.1, 7.2.1
ϕ_t	capacity reduction factor for tension	3.2.1
ϕ_v	capacity reduction factor for shear	3.3.4.1, 7.2.3
ϕ_w	capacity reduction factor for bearing	3.3.6.1, 3.3.8.2
ρ	quantity for load capacity; <i>or</i> effective width factor	1.5.1.2, 2.2.1.2, 2.3.2.2, 2.6.1
ω_k	coefficient	2.6.3.1
ψ	stress ratio f_2^* / f_1^*	2.2.3.2, 2.3.2.2, 3.3.8.3

1.5 MATERIALS

1.5.1 Structural steel

1.5.1.1 Applicable steels

The following apply to structural members:

- (a) AS/NZS 1163, AS 1397 (for Grade G550, less than 0.9 mm in thickness, [see Item (b)], AS/NZS 1594, AS/NZS 1595 and AS/NZS 3678, as appropriate. Steel marking requirements shall be followed as per the applicable Standard.
- (b) Steels conforming to AS 1397, Grade 550, less than 0.9 mm in thickness may be used provided—
 - (i) the yield stress (f_y) used in design in Sections 2, 3, 4 and 7, and the tensile strength (f_u) used in design in Section 5 are taken as 90% of the corresponding specified values or 495 MPa, whichever is the lesser, and for steel less than 0.6 mm in thickness, the yield stress (f_y) used in design in Sections 2, 3, 4 and 7, and the tensile strength (f_u) used in design in Section 5 are taken as 75% of the corresponding specified values or 410 MPa, whichever is the lesser; or
 - (ii) the suitability of such steel is demonstrated by load test in accordance with Section 8.
- (c) For other steels, the properties and suitability of which are in accordance with Clause 1.5.1.4 the yield stress (f_y) and tensile strength (f_u) used in design shall be determined in accordance with Section 8 and AS 1391.

1.5.1.2 Strength increase resulting from cold-forming

Strength increase resulting from cold-forming shall be permitted by substituting the average design yield stress (f_{ya}) of the full section for f_y . Such increase shall be limited to Clauses 3.3 (excluding Clause 3.3.3.2), 3.4, 3.5, 3.6 and 4.4. The limitations and methods for determining f_{ya} shall be as follows:

- (a) For axially loaded compression members and flexural members whose proportions are such that the quantity (ρ) for load capacity is unity, as determined in accordance with Clause 2.2 for each of the component elements of the sections, the average design yield stress (f_{ya}) shall be determined on the basis of one of the following:
 - (i) Full section tensile tests (see Section 8).
 - (ii) Stub column tests (see Section 8).
 - (iii) The following calculation:

$$f_{ya} = Cf_{yc} + (1 - C)f_{yf} \leq f_{uf} \quad \dots 1.5.1.2(1)$$

where

f_{ya} = average design yield stress of the steel in the full section of compression members or full flange sections of flexural members

C = for compression members, ratio of the total bend cross-sectional area to the total cross-sectional area of the full section; and for flexural members, ratio of the total bend cross-sectional area of the controlling flange to the full cross-sectional area of the controlling flange

f_{yc} = tensile yield stress of bends

$$= \frac{B_c f_{yv}}{\left(\frac{r_1}{t}\right)^m} \quad \dots 1.5.1.2(2)$$

Equation 1.5.1.2(2) is applicable only if f_{uv}/f_{yv} is greater than or equal to 1.2, r_i/t is less than or equal to 7 and the minimum included angle is less than or equal to 120°.

$B_c = \text{constant}$

$$= 3.69 \left(\frac{f_{uv}}{f_{yv}} \right) - 0.819 \left(\frac{f_{uv}}{f_{yv}} \right)^2 - 1.79 \quad \dots 1.5.1.2(3)$$

$f_{yv} =$ tensile yield stress of unformed steel

$r_i =$ inside bend radius

$m = \text{constant}$

$$= 0.192 \left(\frac{f_{uv}}{f_{yv}} \right) - 0.068 \quad \dots 1.5.1.2(4)$$

$f_{uv} =$ tensile strength of unformed steel

$f_{yf} =$ yield stress of the flat portions (see Clause 8.1.4); or
yield stress of unformed steel if tests are not made

- (b) For axially loaded tension members, f_{ya} shall be determined by either Item (a)(i) or Item (a)(iii).

1.5.1.3 Effect of welding

The effect of any welding on the mechanical properties of a member shall be determined on the basis of tests on specimens of the full section containing the weld within the gauge length. Any necessary allowance for such effect shall be made in the structural use of the member.

Welded connections for all grades conforming with AS/NZS 1163 and grades G250, G300, G350, G450, G500 and G550 ($t > 0.6$ mm) steel conforming with AS 1397, designed in accordance with Clause 5.2.2 for butt welds, Clause 5.2.3 for fillet welds and Clause 5.2.6 for flare welds do not require further testing providing the f_u of 425 MPa is used for G500 steel and f_u of 450 MPa is used for G550 steel.

1.5.1.4 Ductility

Steels not listed in Clause 1.5.1.1(a) and used for forming structural members and connections shall conform to the following requirements:

- (a) The ratio of tensile strength to yield stress shall be not less than 1.05.
- (b) 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 AS 1391.
- (c) If these requirements cannot be met, the following criteria shall be satisfied:
 - (i) Local elongation in a 13 mm gauge length across the fracture shall be not less than 20%.
 - (ii) Uniform elongation outside the fracture shall be not less than 3%.

1.5.1.5 Acceptance of steels

The marking of steels shall be as specified in the appropriate Standard in Clause 1.5.1.1(a).

The uncoated minimum steel thickness at any location of the cold-formed product, as delivered to the job site, shall be not less than 95% of the value used in its design. However, lesser thicknesses shall be permitted at bends (forming corners) due to cold-forming effects.

1.5.1.6 *Unidentified steel*

If unidentified steel is used, it shall be free from surface imperfections and shall be used only where the particular physical properties of the steel and its weldability will not adversely affect the design capacities and serviceability of the structure. Unless a full test in accordance with AS 1391 is made, the yield stress of the steel used in design (f_y) shall be 170 MPa or less, and the tensile strength used in design (f_u) shall be 300 MPa or less.

1.5.2 **Design stresses**

The minimum yield stress (f_y) and tensile strength (f_u) used in design shall not exceed the values given in Table 1.5.2 for the appropriate steel grade or Clause 1.5.1.1(c).

NOTE: Regardless of the closeness of yield stress and tensile strength of some steels, steel grades given in Table 1.5.2 are suitable for cold-forming provided that an appropriate inside bend radius (r_i) is chosen.

TABLE 1.5.2
MINIMUM STRENGTHS OF STEELS CONFORMING TO
AS/NZS 1163, AS 1397, AS/NZS 1594, AS/NZS 1595 AND AS/NZS 3678

Applicable Standard	Grade	Yield stress (f_y) MPa	Tensile strength (f_u) MPa
AS/NZS 1163	C250 and C250L0	250	320
	C350 and C350L0	350	430
	C450 and C450L0	450	500
AS 1397	G250	250	320
	G300	300	340
	G350	350	420
	G450*	450	480
	G500†	500	520
	G550‡ ($t \geq 0.9$ mm)	550	550
	G550‡ (0.9 mm $> t \geq 0.6$ mm)	495	495
	G550‡ ($t < 0.6$ mm)	413	413
AS/NZS 1594	HA1	(see Note)	(see Note)
	HA3	200	300
	HA4N	170	280
	HA200	200	300
	HA250, HU250	250	350
	HA250/1	250	350
	HA300, HU300	300	400
	HA300/1, HU300/1	300	430
	HW350	350	430
	HW350	340	450
	HA400	380	460
	XF300	300	440
	XF400	380	460
	XF500	480	570
AS/NZS 1595	CA220	210	340
	CA260	250	350
	CW300	300	450
	CA350	350	430
	CA500	500	510
AS/NZS 3678	200 ($t \leq 8$ mm)	200	300
	200 (8 mm $< t \leq 12$ mm)	200	300
	250, 250L15 ($t \leq 8$ mm)	280	410
	250, 250L15 (8 mm $< t \leq 12$ mm)	260	410
	250, 250L15 (12 mm $< t \leq 20$ mm)	250	410
	250, 250L15 (20 mm $< t \leq 25$ mm)	250	410
	300, 300L15 ($t \leq 8$ mm)	320	430
	300, 300L15 (8 mm $< t \leq 12$ mm)	310	430
	300, 300L15 (12 mm $< t \leq 20$ mm)	300	430
	300, 300L15 (20 mm $< t \leq 25$ mm)	280	430
	350, 350L15 ($t \leq 8$ mm)	360	450
	350, 350L15 (8 mm $< t \leq 12$ mm)	360	450
	350, 350L15 (12 mm $< t \leq 20$ mm)	350	450
	350, 350L15 (20 mm $< t \leq 25$ mm)	340	450

(continued)

TABLE 1.5.2 (continued)

Applicable Standard	Grade	Yield stress (f_y) MPa	Tensile strength (f_u) MPa
	400, 400L15 ($t \leq 8$ mm)	400	480
	400, 400L15 ($8 \text{ mm} < t \leq 12$ mm)	400	480
	400, 400L15 ($12 \text{ mm} < t \leq 20$ mm)	380	480
	400, 400L15 ($20 \text{ mm} < t \leq 25$ mm)	360	480
	450, 450L15 ($t \leq 8$ mm)	450	520
	450, 450L15 ($8 \text{ mm} < t \leq 12$ mm)	450	520
	450, 450L15 ($12 \text{ mm} < t \leq 20$ mm)	450	520
	450, 450L15 ($20 \text{ mm} < t \leq 25$ mm)	420	500
	WR350, WR350/L0 ($t \leq 8$ mm)	340	450
	WR350, WR350/L0 ($8 \text{ mm} < t \leq 12$ mm)	340	450
	WR350, WR350/L0 ($12 \text{ mm} < t \leq 20$ mm)	340	450
	WR350, WR350/L0 ($20 \text{ mm} < t \leq 25$ mm)	340	450

* Applies to hard-rolled material of thickness greater than or equal to 1.5 mm.

† Applies to hard-rolled material of thickness greater than 1.0 mm but less than 1.5 mm.

‡ Applies to hard-rolled material of thickness less than or equal to 1.0 mm.

NOTE: For design purposes, yield and tensile strengths approximate those of structural Grade HA200. For specific information contact the supplier.

1.5.3 Fasteners and electrodes

1.5.3.1 Steel bolts, nuts and washers

Steel bolts, nuts and washers shall conform to AS 1110.1, AS 1111.1, AS 1112.1, AS 1112.2, AS 1112.3, AS 1112.4, AS/NZS 1252.1 and AS 4291.1 (ISO 898-1), as appropriate.

High-strength fasteners, other than those conforming to AS/NZS 1252.1, may be used, provided that evidence of their equivalence to high-strength bolts conforming to AS/NZS 1252.1 is available.

1.5.3.2 Welding consumables

All welding consumables shall conform to AS/NZS 1554.1, AS/NZS 1554.5 and AS/NZS 1554.7, as appropriate.

1.5.3.3 Screws

Self-drilling screws shall conform to AS 3566.1 and AS 3566.2.

1.5.3.4 Blind rivets

Blind rivets shall conform to the Industrial Fastener Institute document, IFI 114.

1.6 DESIGN REQUIREMENTS

1.6.1 Actions and combination of actions

A structure and its components shall be designed for the actions and combination of actions as specified in AS/NZS 1170.0 or NASH Standard—*Residential and Low-rise Steel Framing, Part 1: Design Criteria*.

1.6.2 Structural analysis and design

Structural analysis and design shall be in accordance with AS/NZS 1170.0. First and second order elastic analyses as well as advanced analysis are used as defined in Appendix B. In the application of the combined compression and bending equations in Clause 3.5.1, first order elastic analysis according to Paragraph B2, Appendix B, shall be used. In the application of the combined compression and bending equations in Clause 7.2.4, second order elastic analysis according to Paragraph B3, Appendix B, shall be used.

Alternatively, first order elastic analysis may be used with Clause 7.2.4 provided the combined compression and bending equations in Clause 3.5.1 are used.

NOTE: Advanced analysis may be used for the prequalified systems in Paragraph B4, Appendix B in lieu of the member design methods given in Sections 3 and 7.

1.6.3 Design capacity

The design capacity (R_d) shall be determined by any one of the following:

- (a) The nominal capacity (R_u) in accordance with Sections 2 to 7 and the capacity reduction factor (ϕ) given in Table 1.6.3 as appropriate, i.e. $R_d = \phi R_u$.
- (b) Testing in accordance with Clause 8.4.
- (c) Where the composition or configuration of such components is such that Item (a) or (b) cannot be made in accordance with those provisions, structural performance shall be established from the design capacity or stiffness by rational engineering analysis based on appropriate theory, related testing if data is available and engineering judgement. Specifically, the design capacity shall be determined from the calculated nominal capacity by applying the following capacity reduction factors:
 - (i) For members $\phi = 0.80$.
 - (ii) For connections $\phi = 0.65$.
- (d) Advanced analysis for prequalified structures in accordance with Paragraph B4, Appendix B.

1.6.4 Earthquake design

1.6.4.1 For Australia

All structures shall be designed for the actions and combination of actions specified in AS 1170.4—2007. If cold-formed steel members are used as the primary earthquake resistance element, then the structural ductility factor (μ) shall be as specified in Clause 1.6.4.2.2, and the structural performance factor (S_p) shall be as specified in Clause 1.6.4.2.4.

NOTE: If higher values of μ are to be used, reference should be made to NZS 1170.5 as in Clause 1.6.4.2.3.

The design action effects for earthquake loads shall be obtained using either the equivalent static analysis of Section 6 of AS 1170.4—2007 or the dynamic analysis of Section 7 of AS 1170.4—2007.

1.6.4.2 For New Zealand and limited application in Australia

1.6.4.2.1 General

All structures shall be designed for the actions specified in NZS 1170.5 and combination of actions specified in AS/NZS 1170.0, subject to the limitations specified in Clauses 1.6.4.2.2 to 1.6.4.2.4.

1.6.4.2.2 Structural ductility factor

For the ultimate limit state, the structural ductility factor (μ) shall be taken as follows:

- (a) For seismic-resisting systems involving an assemblage of elements acting as a single unit, μ shall be less than or equal to 1.25.
- (b) For seismic-resisting systems using semi-rigid connections, μ shall be less than or equal to 1.25.
- (c) Where a special study is undertaken (see Clause 1.6.4.2.3), μ may be increased, but shall not be greater than 4.0 when deflection-limited performance at serviceability is required and not greater than 6.0 in other cases.

- (d) For all other earthquake-resisting systems, $\mu = 1.0$.

For the serviceability limit state, $\mu = 1.0$.

NOTES:

- 1 An example of an assemblage of elements is a braced wall panel, where the whole panel and its attachments at the top and base contribute to the earthquake resistance.
- 2 Earthquake resisting systems using semi-rigid connections cover frames with connections that are flexurally weaker than the members framing into the connection.

1.6.4.2.3 *Special studies*

Where it is demonstrated by special study that μ for a particular structural system is greater than 1.25, then—

- (a) μ shall be based specifically from the special study including—
 - (i) structural form and configuration under consideration;
 - (ii) ductility of the material;
 - (iii) location of yielding regions of the structure;
 - (iv) structural damping characteristics involved in the structural system; and
 - (v) need to provide the structure with a small margin against collapse under the maximum considered event in accordance with NZS 1170.5;
- (b) where μ greater than 1.25 is applicable to a design, then capacity design shall be used in order to protect elements of the earthquake resisting system from inelastic demands beyond their capability to dependably resist such demands; and
- (c) for buildings containing one or more suspended floors, capacity design principles shall be used to suppress inelastic demand in individual column members.

1.6.4.2.4 *Structural performance factor*

When considering lateral stability of a whole structure, the structural performance factor (S_p) shall be taken as 1.0.

For the ultimate limit state, S_p shall be taken as follows:

- (a) Where μ is less than or equal to 2.0, but not less than 1.0—

$$S_p = 1.3 - 0.3\mu \quad \dots 1.6.4.2.4$$

- (b) Where μ is greater than 2.0, then $S_p = 0.70$.

For the serviceability limit state, $S_p = 0.70$.

1.6.5 **Durability**

1.6.5.1 *General*

A structure shall be designed to perform its required functions during its expected life.

Where steelwork in a structure is to be exposed to a corrosive environment, the steelwork shall be given protection against corrosion. The degree of protection shall be determined after consideration has been given to the use of the structure, its maintenance and the climatic or other local conditions.

1.6.5.2 *Corrosion protection*

NOTE: Corrosion protection should conform to AS/NZS 2311 and AS/NZS 2312, as appropriate. For further information, see Appendix C. Additional information is available in NASH Standard, *Residential and Low-rise Steel Framing, Part 2: Design Solutions*.

TABLE 1.6.3
CAPACITY REDUCTION FACTOR

Design capacity	Reference	Capacity reduction factor (ϕ)
(a) Stiffeners:	3.3.8	
Transverse stiffeners (ϕ_c)	3.3.8.1	0.85
Bearing stiffeners (ϕ_w)	3.3.8.2	0.90
Shear stiffeners (ϕ_v)	3.3.8.3	0.90
(b) Members subject to axial tension (ϕ)	3.2	0.90
(c) Members subject to bending:	3.3	
Section moment capacity—	3.3.2	
for sections with stiffened or partially stiffened compression flanges (ϕ_b)	3.3.2	0.95
for sections with unstiffened compression flanges (ϕ_b)	3.3.2	0.90
Member moment capacity—	3.3.3	
members subject to lateral buckling (ϕ_b)	3.3.3.2	0.90
members subject to distortional buckling (ϕ_b)	3.3.3.3	0.90
beams having one flange through-fastened to sheeting (channel or Z-sections) (ϕ_b)	3.3.3.4	0.90
Web design—		
shear (ϕ_v)	3.3.4	0.90
Bearing (ϕ_w)—	3.3.6	
for back-to-back sections	Table 3.3.6.2(A)	0.75–0.90
for single web channel-sections and C-sections	Table 3.3.6.2(B)	0.75–0.90
for single web Z-sections	Table 3.3.6.2(C)	0.75–0.90
for single hat sections	Table 3.3.6.2(D)	0.75–0.90
for multiple web deck sections	Table 3.3.6.2(E)	0.60–0.90
(d) Concentrically loaded compression members (ϕ_c)	3.4	0.85
(e) Combined axial load and bending:	3.5	
Compression (ϕ_c)	3.5.1	0.85
Bending (ϕ_b)—	3.5.1	
using Clause 3.3.2		0.90 or 0.95
using Clause 3.3.3.1		0.90
(f) Cylindrical tubular members:	3.6	
Bending (ϕ_b)	3.6.2	0.95
Compression (ϕ_c)	3.6.3	0.85
(g) Welded connections:	5.2	
Butt welds—	5.2.2	
tension or compression	5.2.2.1	0.90
shear	5.2.2.2(a)	0.80
shear (base metal)	5.2.2.2(b)	0.90

(continued)

TABLE 1.6.3 (continued)

Design capacity	Reference	Capacity reduction factor (ϕ)
Fillet welds—	5.2.3	
longitudinal loading	5.2.3.2	0.55 or 0.60
transverse loading	5.2.3.3	0.60
Arc spot welds (puddle welds)—	5.2.4	
shear (welds)	5.2.4.2(a)	0.60
shear (connected part)	5.2.4.2(b)	0.50 or 0.60
shear (tearout)	5.2.4.3	0.60 or 0.70
tension	5.2.4.4	0.65
Arc seam welds—	5.2.5	
shear (welds)	5.2.5.2(a)	0.60
shear (connected part)	5.2.5.2(b)	0.60
Flare welds—	5.2.6	
transverse loading	5.2.6.2(a)	0.55
longitudinal loading	5.2.6.2(b)	0.55
Resistance welds—	5.2.7	
spot welds	5.2.7(a)	0.65
(h) Bolted connections:	5.3	
Tearout	5.3.2	0.60 or 0.70
Net section tension	5.3.3	0.80
Bearing	5.3.4	0.60
Bolts—	5.3.5	
bolt in shear	5.3.5.1	0.80
bolt in tension	5.3.5.2	0.80
(i) Screwed connections:	5.4	
Screwed connections in shear—	5.4.2	
tension in the connected part	5.4.2.3	0.65
tilting and hole bearing	5.4.2.4	0.5
tearout (limited by end distance)	5.4.2.5	0.60 or 0.70
Screwed connections in tension—	5.4.3	
pull-out of connected parts	5.4.3.2	0.5
pull-over (pull-through) of connected parts	5.4.3.2	0.5
(j) Power-actuated fasteners:	5.5	
Power-actuated fasteners in tension—	5.5.2	
PAF in tension	5.5.3.1	0.60
Pull-out	5.5.3.3	0.40
Pull-over	5.5.3.4	0.50
Power-actuated fastener in shear—	5.5.4	
Shear strength	5.5.4.2	0.60
Bearing and tilting strength	5.5.4.3	0.80

(continued)

TABLE 1.6.3 *(continued)*

Design capacity	Reference	Capacity reduction factor (ϕ)
Pull-out strength	5.5.4.4	0.65
(k) Blind riveted connections:	5.6	
Riveted connections in shear—	5.6.2	
tension in the connected part	5.6.2.2	0.65
tilting and hole bearing	5.6.2.3	0.50
tearout	5.6.2.4	0.65
(l) Rupture:		
Shear rupture	5.7.1	0.75
Block shear rupture (bolted connections)	5.7.3	0.80

SECTION 2 ELEMENTS

2.1 SECTION PROPERTIES

2.1.1 General

Properties of sections, such as cross-sectional area, second moment of area, section modulus, radius of gyration, and centroid, shall be determined in accordance with conventional methods by division of the section shape into simple elements, including bends.

Properties shall be based on nominal dimensions and nominal base steel thickness (see Clause 1.5.1.6).

2.1.2 Design procedures

2.1.2.1 *Full section properties*

Properties of full, unreduced sections shall be based on the entire simplified shape with the flats and bends located along the element mid-lines unless the manufacturing process warrants consideration of a more accurate method.

To calculate the stability of members, a simplified shape where the bends are eliminated and the section is represented by straight mid-lines may be used when calculating the following properties:

- (a) Parameters for distortional buckling (see Appendix D).
- (b) Location of shear centre (see Paragraph E1 of Appendix E).
- (c) Warping constant (see Paragraph E1 of Appendix E).
- (d) Monosymmetry section constant (see Paragraph E2 of Appendix E).

2.1.2.2 *Effective section properties*

For the design of cold-formed members with slender elements by the effective width method, the area of the sections shall be reduced at specified locations.

The reduction of the area is required to—

- (a) compensate for the effects of shear lag (see Clause 2.1.3.3); and
- (b) compensate for local instabilities of elements in compression (see Clauses 2.2 to 2.5).

2.1.2.3 *Location of reduced width*

The location of reduced width shall be determined as follows:

- (a) For the design of uniformly compressed stiffened elements, the location of the lost portion shall be taken at the middle of the element (see Figures 2.2.1 and 2.4.2(b)).
- (b) For the design of stiffened elements under a stress gradient or where only a part of the element is in compression (e.g. the webs), the location of the lost portion shall be as shown in Figure 2.2.3.
- (c) For unstiffened elements, under either a stress gradient or uniform compression, the lost portion shall be taken at the unstiffened edge as shown in Figure 2.3.1. If the unstiffened element is subjected to both tension and compression across its width, the lost portion may be taken as specified in Clause 2.3.2.
- (d) For the design of elements with an edge stiffener, the location of the lost portion shall be as shown in Figure 2.4.2.

2.1.3 Dimensional limits

2.1.3.1 Maximum flat-width-to-thickness ratios for use with the effective width method

The maximum overall flat-width-to-thickness ratios (b/t), disregarding intermediate stiffeners and taking t as the nominal thickness of the element, shall be as follows:

- (a) For a stiffened compression element having one longitudinal edge connected to a web or flange element and the other stiffened by—
 - (i) simple lip 60; and
 - (ii) any other kind of stiffener when—
 - (A) $I_s < I_a$ 60; and
 - (B) $I_s \geq I_a$ 90.
- (b) For a stiffened compression element with both longitudinal edges connected to other stiffened elements 500.
- (c) For a unstiffened compression element 60.

NOTE: Unstiffened compression elements with b/t ratios greater than 30 and stiffened compression elements with b/t ratios greater than 250 are likely to develop noticeable deformation at the full design load, without affecting the ability of the member to carry the design load. Stiffened elements with b/t ratios greater than 500 can be used with adequate design capacity to sustain the design loads. However, substantial deformations of such elements usually will invalidate the design equations of this Standard.

2.1.3.2 Flange curling

Where the flange of a flexural member is unusually wide and it is desired to limit the maximum amount of curling or movement of the flange toward the neutral axis, the maximum width (b_1) of the compression and tension flanges, either stiffened or unstiffened projecting beyond the web for I-beams and similar sections or the maximum half distance (b_1) between webs for box- or U-type beams, shall be determined from the following equation:

$$b_1 = \sqrt{\frac{0.061 t_f d E}{f_{av}^*}} \sqrt[4]{\frac{100 c_f}{d}} \quad \dots 2.1.3.2$$

where

t_f = thickness of the flange

d = depth of the section

f_{av}^* = average design stress in the full, unreduced flange width (see Note 1)

c_f = amount of curling (see Note 2)

NOTES:

- 1 Where members are designed by the effective design width procedure, the average stress equals the maximum stress multiplied by the ratio of the effective design width to the actual width.
- 2 The amount of curling that can be tolerated will vary with different kinds of sections and should be established by the designer. Amount of curling in the order of 5% of the depth of the section is usually not considered excessive.

2.1.3.3 Shear lag effects (usually short spans supporting concentrated loads)

Where the span of the beam (l) is less than $30b_1$ and the beam carries one concentrated load, or several loads spaced greater than $2b_1$, the effective design width of any flange, whether in tension or compression, shall be limited to the values given in Table 2.1.3.3.

For flanges of I-beams and similar sections stiffened by lips at the outer edges, b_1 shall be taken as the sum of the flange projection beyond the web and the depth of the lip.

TABLE 2.1.3.3
MAXIMUM RATIO OF EFFECTIVE
DESIGN WIDTH TO ACTUAL WIDTH
FOR SHORT WIDE FLANGE BEAMS

l/b_1	Ratio	l/b_1	Ratio
30	1.00	14	0.82
25	0.96	12	0.78
20	0.91	10	0.73
18	0.89	8	0.67
16	0.86	6	0.55

LEGEND:

l = full span for simple beams; *or*
distance between inflection points for continuous beams; *or*
twice the length of cantilever beams

2.1.3.4 Maximum web depth-to-thickness ratio

The maximum web depth-to-thickness ratio (d_1/t_w) of flexural members shall not exceed the following:

- (a) For unreinforced webs— d_1/t_w 200.
- (b) For webs with transverse stiffeners conforming to Clause 3.3.8.1—
 - (i) if using bearing stiffeners only— d_1/t_w 260; and
 - (ii) if using bearing stiffeners and intermediate stiffeners— d_1/t_w 300;

where

d_1 = depth of the flat portion of the web measured along the plane of the web

t_w = thickness of web

Where a web consists of two or more sheets, the ratio d_1/t_w shall be calculated for each sheet.

2.2 EFFECTIVE WIDTHS OF STIFFENED ELEMENTS

2.2.1 Uniformly compressed stiffened elements

2.2.1.1 General

For uniformly compressed stiffened elements (see Figure 2.2.1), the effective widths for section or member capacity and deflection calculations shall be determined in accordance with Clauses 2.2.1.2 and 2.2.1.3 respectively.

2.2.1.2 Effective width for capacity calculations

For determining the section or member capacity, the effective widths (b_e) of uniformly compressed stiffened elements shall be determined from Equation 2.2.1.2(1) or Equation 2.2.1.2(2), as appropriate.

For $\lambda \leq 0.673$: $b_e = b$ 2.2.1.2(1)

For $\lambda > 0.673$: $b_e = \rho b$ 2.2.1.2(2)

where

b = flat width of element excluding radii (see in Figure 2.2.1(a))

ρ = effective width factor

$$= \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \leq 1.0 \quad \dots 2.2.1.2(3)$$

The slenderness ratio (λ) shall be determined as follows:

$$\lambda = \sqrt{\frac{f^*}{f_{cr}}} \quad \dots 2.2.1.2(4)$$

where

f^* = design stress in the compression element calculated on the basis of the effective design width (see Figure 2.2.1(b))

f_{cr} = plate elastic buckling stress

$$= \left(\frac{k\pi^2 E}{12(1-\nu^2)} \right) \left(\frac{t}{b} \right)^2 \quad \dots 2.2.1.2(5)$$

k = plate buckling coefficient

= 4 for stiffened elements supported by a web on each longitudinal edge (k values for different types of elements are given in the applicable clauses)

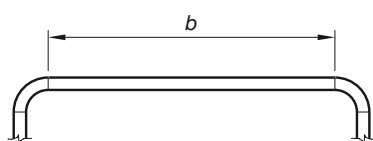
E = Young's modulus of elasticity (200×10^3 MPa)

ν = Poisson's ratio

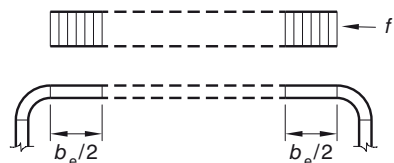
= 0.3

t = thickness of the uniformly compressed stiffened elements

Alternatively, the plate buckling coefficient (k) for each flat element may be determined from a rational elastic buckling analysis of the whole section as a plate assemblage subjected to the longitudinal stress distribution in the section prior to buckling.



(a) Actual element



(b) Effective width (b_e) of element and design stress (f^*) on effective element

FIGURE 2.2.1 STIFFENED ELEMENTS WITH UNIFORM COMPRESSION

For determining the nominal section or member capacity of flexural members, the design stress (f^*) shall be taken as follows:

- (a) If the nominal section moment capacity (M_s) is based on initiation of yielding as specified in Clause 3.3.2.2, and the initial yielding of the element being considered is in compression, then f^* shall be equal to f_y . If the initial yielding of the section is in tension, then f^* of the element being considered shall be determined on the basis of the effective section at M_y (moment causing initial yield).
- (b) If the nominal section moment capacity (M_s) is based on inelastic reserve capacity as specified in Clause 3.3.2.3, then f^* shall be the stress of the element being considered at M_s . The effective section shall be used to determine M_s .
- (c) If the nominal member moment capacity (M_b) is based on lateral buckling as specified in Clause 3.3.3.2 or on distortional buckling as specified in Clause 3.3.3.3, then f^* shall be equal to f_c as described in Clauses 3.3.3.2 and 3.3.3.3 in determining Z_c .

For determining the nominal section or member compression capacity, f^* shall be taken as follows:

- (i) If the nominal section capacity (N_s) of the member in compression is based on initiation of yielding as specified in Clause 3.4, then f^* shall be equal to f_y .
- (ii) If the nominal member capacity (N_c) of the member in compression is based on flexural, torsional or flexural-torsional buckling as specified in Clause 3.4, then f^* shall be equal to f_n , as specified in Clauses 3.4.1 and 3.4.6.

2.2.1.3 Effective width for deflection calculations

For determining the deflection, the effective widths (b_{ed}) shall be determined from Equation 2.2.1.3(1) or Equation 2.2.1.3(2), as appropriate.

$$\text{For } \lambda \leq 0.673: b_{ed} = b \quad \dots 2.2.1.3(1)$$

$$\text{For } \lambda > 0.673: b_{ed} = \rho b \quad \dots 2.2.1.3(2)$$

The effective width factor (ρ) shall be determined by either of the following two procedures:

- (a) *Procedure I* A low estimate of the effective width may be obtained from Equations 2.2.1.2(3) and 2.2.1.2(4), except that f_d^* is substituted for f^* where f_d^* is the design compressive stress in the element being considered based on the effective section at the load for which deflections are determined.
- (b) *Procedure II* For stiffened elements supported by a web on each longitudinal edge, an improved estimate of the effective width can be obtained by calculating ρ from Equations 2.2.1.3(3) to 2.2.1.3(5), as appropriate.

$$\text{For } \lambda \leq 0.673: \rho = 1 \quad \dots 2.2.1.3(3)$$

$$\text{For } 0.673 < \lambda < \lambda_c: \rho = \frac{1.358 - \frac{0.461}{\lambda}}{\lambda} \leq 1.0 \quad \dots 2.2.1.3(4)$$

$$\text{For } \lambda \geq \lambda_c: \rho = \frac{0.41 + 0.59 \sqrt{\frac{f_y}{f_d^*}} - \frac{0.22}{\lambda}}{\lambda} \leq 1.0 \quad \dots 2.2.1.3(5)$$

$$\lambda_c = 0.256 + 0.328 \left(\frac{b}{t} \right) \sqrt{\frac{f_y}{E}} \quad \dots 2.2.1.3(6)$$

where λ shall be calculated from Equation 2.2.1.2(4) except that f_d^* is substituted for f^* .

2.2.2 Uniformly compressed stiffened elements with circular or non-circular holes

2.2.2.1 General

For uniformly compressed stiffened elements with circular holes or non-circular holes, the effective widths for section or member capacity and deflection calculations shall be determined in accordance with Clauses 2.2.2.2 and 2.2.2.3, respectively.

2.2.2.2 Effective width for capacity calculations

2.2.2.2.1 For circular holes

For determining the section or member capacity, where $0.50 \geq d_h/b \geq 0$ and $b/t \leq 70$, and the centre-to-centre spacing of holes $>0.5b$ and $>3d_h$, the effective width (b_e) of uniformly compressed stiffened elements with circular holes shall be determined from Equation 2.2.2.2.1(1) or Equation 2.2.2.2.1(2), as appropriate.

$$\text{For } \lambda \leq 0.673: \quad b_e = b - d_h \quad \dots 2.2.2.2.1(1)$$

$$\text{For } \lambda > 0.673: \quad b_e = \frac{b \left(1 - \frac{0.22}{\lambda} - \frac{0.8d_h}{b} + \frac{(0.085d_h)}{b\lambda} \right)}{\lambda} \leq b - d_h \quad \dots 2.2.2.2.1(2)$$

where d_h is the diameter of holes and λ shall be calculated in accordance with Clause 2.2.1.2.

The value of b_e shall not exceed $(b - d_h)$.

2.2.2.2.2 For non-circular holes

A uniformly compressed stiffened element with non-circular holes shall be assumed to consist of two unstiffened strips of flat width, c , adjacent to the holes (additional notation in this Clause is illustrated in Figure 2.2.2). The effective width b_e of each unstiffened strip adjacent to the hole shall be determined in accordance with Clause 2.2.1.2 except that the plate buckling coefficient, k , shall be taken as 0.43, and b as c . These provisions shall be applicable within the following limits:

- (a) Centre-to-centre hole spacing $s \geq 600 \text{ mm}$.
- (b) Clear distance from the hole at the ends $s_{\text{end}} \geq 250 \text{ mm}$.
- (c) Depth of hole $d_h \leq 65 \text{ mm}$.
- (d) Length of hole $L_h \leq 115 \text{ mm}$.
- (e) Ratio of depth of hole, d_h , to the out-to-out width, b_o $d_h/b_o \leq 0.5$.

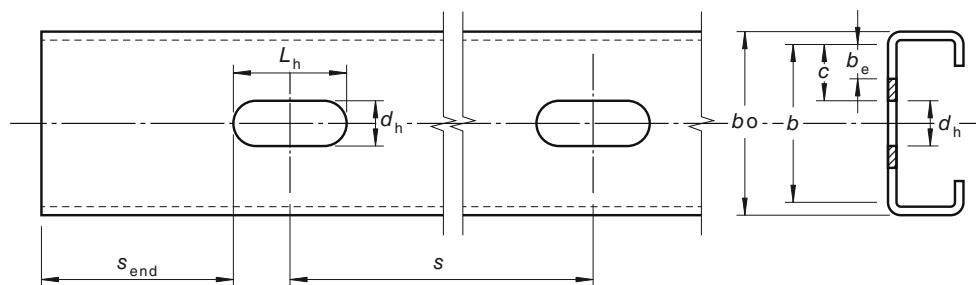


FIGURE 2.2.2 UNIFORMLY STIFFENED ELEMENTS WITH NON-CIRCULAR HOLES

2.2.2.3 Effective width for deflection calculations

For determining the deflection, the effective width (b_{ed}) shall be equal to be determined in accordance with Procedure I of Clause 2.2.1.3 except that f_d^* is substituted for f^* where f_d^* is the design compressive stress of the element being considered, based on the effective section at the load for which deflections are determined.

2.2.3 Stiffened elements with stress gradient

2.2.3.1 General

For stiffened elements with stress gradient (see Figure 2.2.3), the effective widths for section or member capacity and deflection calculations shall be determined in accordance with Clauses 2.2.3.2 and 2.2.3.3, respectively.

2.2.3.2 Effective width for capacity calculations

For determining the section or member capacity, the effective width (b_{e1}) (see Figure 2.2.3) shall be determined from the following:

$$b_{e1} = \frac{b_e}{3 - \psi} \quad \dots 2.2.3.2(1)$$

The effective width (b_{e2}) (see Figure 2.2.3) shall be determined from Equation 2.2.3.2(2) or Equation 2.2.3.2(3), as appropriate.

$$\text{For } \psi \leq -0.236: b_{e2} = \frac{b_e}{2} \quad \dots 2.2.3.2(2)$$

$$\text{For } \psi > -0.236: b_{e2} = b_e - b_{e1} \quad \dots 2.2.3.2(3)$$

where

b_e = effective width determined in accordance with Clause 2.2.1.2 with f_1^* substituted for f^* and with k determined as follows:

$$k = 4 + 2(1 - \psi)^3 + 2(1 - \psi) \quad \dots 2.2.3.2(4)$$

$$\psi = \frac{f_2^*}{f_1^*} \quad \dots 2.2.3.2(5)$$

f_1^*, f_2^* = web stresses calculated on the basis of the effective section (see Figure 2.2.3)

f_1^* is compression (+) and f_2^* may be either tension (−) or compression (+). In case f_1^* and f_2^* are both compression, f_1^* shall be greater than or equal to f_2^* .

In addition, ($b_{e1} + b_{e2}$) shall not exceed the compression portion of the web calculated on the basis of effective section.

2.2.3.3 Effective width for deflection calculations

For determining the deflection, the effective widths (b_{e1}) and (b_{e2}) shall be determined in accordance with Clause 2.2.3.2 except that f_{d1}^* and f_{d2}^* are substituted for f_1^* and f_2^* . The calculated stresses f_1^* and f_2^* (see Figure 2.2.3) shall be used to determine f_{d1}^* and f_{d2}^* , respectively. Calculations shall be based on the effective section for the load for which deflections are determined.

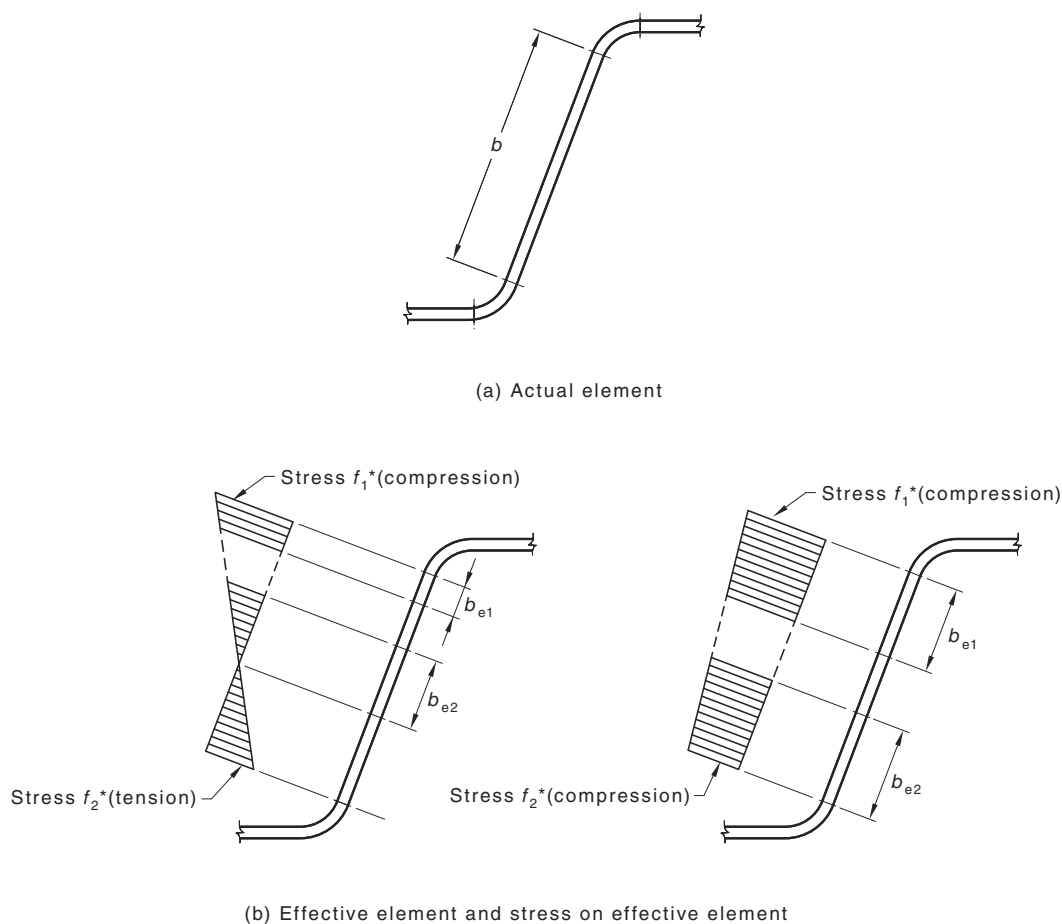


FIGURE 2.2.3 STIFFENED ELEMENTS AND WEBS WITH STRESS GRADIENT

2.2.4 Channel-section webs with holes and with stress gradient

2.2.4.1 General

The calculation of capacity and deflection for channel-section webs with holes and with stress gradient shall be applicable within the following limits:

- (a) $d_{wh}/d_1 < 0.7$. . . 2.2.4.1

where

d_{wh} = depth of the web hole

d_1 = depth of the flat portion of the web measured along the plane of the web

- (b) $d_1/t \leq 200$.
- (c) Holes centred at mid-depth of the web.
- (d) Clear distance between holes is greater than or equal to 450 mm.
- (e) Non-circular holes corner radii greater than or equal to $2t$.
- (f) Non-circular holes with $d_{wh} \leq 65$ mm and $b \leq 115$ mm, where b is the length of the web hole.
- (g) Circular hole diameters less than or equal to 150 mm.
- (h) $d_{wh} > 15$ mm.

2.2.4.2 Capacity calculations

When $d_{wh}/d_1 < 0.38$, the effective widths (b_{e1}) and (b_{e2}) shall be determined in accordance with Clause 2.2.3.2 by assuming no hole exists in the web.

When $d_{wh}/d_1 \geq 0.38$, the effective width shall be determined in accordance with Clause 2.3.1 assuming the compression portion of the web consists of an unstiffened element adjacent to the hole with $f^* = f_1$ as shown in Figure 2.3.2.

2.2.4.3 Deflection calculations

The effective widths shall be determined in accordance with Clause 2.2.3 by assuming no hole exists in the web.

2.2.5 Uniformly compressed elements restrained by intermittent connections

2.2.5.1 General

The provisions of this Clause shall apply to uniformly compressed elements of flexural members only. The provisions shall be limited to multiple flute built-up members having edge-stiffened cover plates. When the spacing of fasteners, s , of a uniformly compressed element restrained by intermittent connections is not greater than the limits specified in Clause 4.1.3, the effective width shall be calculated in accordance with Clause 2.2.1. When the spacing of fasteners is greater than the limits specified in Clause 4.1.3, the effective width shall be determined in accordance with Clauses 2.2.5.2 and 2.2.5.3 below.

2.2.5.2 Capacity calculations

The effective width of the uniformly compressed element restrained by intermittent connections shall be determined as follows:

- (a) When $f < f_c$, the effective width of the compression element between connection lines shall be calculated in accordance with Clause 2.2.1.2.
- (b) When $f \geq f_c$, the effective width of the compression element between connection lines shall be calculated in accordance with Clause 2.2.1.2, except that a reduction factor ρ shall be determined as follows:

$$\rho = \rho_t \rho_m \leq \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} \quad \dots 2.2.5.2(1)$$

where

$$\rho_t = \frac{\left(1 - \frac{0.22}{\lambda_t}\right)}{\lambda_t} \leq 1.0 \quad \dots 2.2.5.2(2)$$

$$\lambda_t = \sqrt{\frac{f_c}{f_{cr}}} \quad \dots 2.2.5.2(3)$$

$$f_c = \text{critical column buckling stress of compression element} = 3.29 E/(s/t)^2 \quad \dots 2.2.5.2(4)$$

s = centre to centre spacing of connectors in the line of compression stress (see Figure 2.2.5)

t = thickness of cover plate in compression

f_{cr} = critical buckling stress defined by Equation 2.2.1.2(5), where b is the transverse spacing of connectors

$$\rho_m = 8 \frac{f_y}{f} \sqrt{\frac{t f_c}{d f}} \leq 1.0 \quad \dots 2.2.5.2(5)$$

d = overall depth of built up member

f = stress in compression element restrained by intermittent connections when the controlling extreme fibre stress is f_y

The provisions of this Section shall apply to shapes that meet the following limits:

- (i) $38 \text{ mm} \leq d \leq 190 \text{ mm}$.
- (ii) $0.9 \text{ mm} \leq t \leq 1.5 \text{ mm}$.
- (iii) $50 \text{ mm} \leq s \leq 200 \text{ mm}$.
- (iv) $228 \text{ MPa} \leq f_y \leq 414 \text{ MPa}$.
- (v) $100 \leq b/t \leq 350$.

The effective width of the edge stiffener and the flat portion, e , shall be determined in accordance with Clause 2.4.2 with modifications as follows:

(A) For $f < f_c$

$$b = e \quad \dots 2.2.5.2(6)$$

(B) For $f \geq f_c$

For the flat portion, e , the effective width, b_e , in Equations 2.4.2(5) and 2.4.2(6) shall be calculated in accordance with Clause 2.2.1.2 with—

- (1) b taken as e ;
- (2) if $d_l/e \leq 0.8$, k is determined in accordance with Table 2.4.2, if $d_l/e > 0.8$, $k = 1.25$; and
- (3) ρ calculated using Equation 2.2.5.2(1) in lieu of Equation 2.2.1.2(3),

where

b = flat width of element measured between longitudinal connection lines and exclusive of radii at stiffeners

e = flat width between the first line of connector and the edge stiffener. See Figure 2.2.5

d_l = overall length of stiffener as defined in Clause 2.4

For the edge stiffener, d_s and I_a shall be determined using b' and f' in lieu of b and f respectively.

$$b' = 2e + \text{minimum of } 0.75s \text{ and } b_1 \quad \dots 2.2.5.2(7)$$

$$f' = \text{maximum of } \rho_m f \text{ and } f_c \quad \dots 2.2.5.2(8)$$

where

f' = stress used in 2.4.2 for determining effective width of edge stiffener

f_c = buckling stress of cover plate determined in accordance with Equation 2.2.5.2(4)

b' = equivalent flat width for determining the effective width of the edge stiffener

b_1 = transverse spacing between the first and the second line of fasteners in the compression element (see Figure 2.2.5).

The provisions of this Clause (2.2.5) shall not apply to single flute members having compression plates with edge stiffeners.

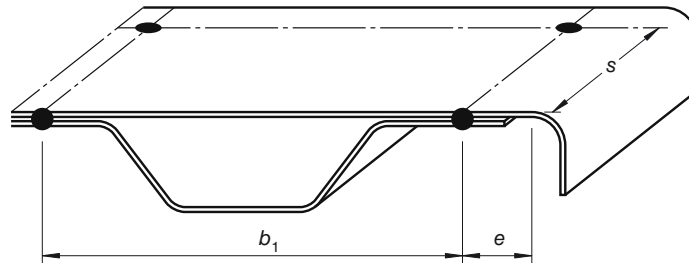


FIGURE 2.2.5 DIMENSION ILLUSTRATION OF CELLULAR DECK

2.2.5.3 Deflection calculations

The effective width of the uniformly compressed element restrained by intermittent connections used for computing deflection shall be determined in accordance with Clause 2.2.5.2 except that—

- (a) f_d shall be substituted for f , where f_d is the computed compression stress in the element being considered at service load; and
- (b) the maximum extreme fibre stress in the built-up member shall be substituted for f_y .

2.3 EFFECTIVE WIDTHS OF UNSTIFFENED ELEMENTS

2.3.1 Uniformly compressed unstiffened elements

2.3.1.1 General

For uniformly compressed unstiffened elements (see Figure 2.3.1), the effective widths for section or member capacity and deflection calculations shall be determined in accordance with Clauses 2.3.1.2 and 2.3.1.3, respectively.

2.3.1.2 Effective width for capacity calculations

For determining the section or member capacity, the effective widths (b_e) of uniformly compressed unstiffened elements shall be determined in accordance with Clause 2.2.1.2 with the exception that k shall be taken as 0.43 and b shall be as shown in Figure 2.3.1.

2.3.1.3 Effective width for deflection calculations

For determining the deflection, the effective widths (b_e) shall be determined in accordance with Procedure I of Clause 2.2.1.3 except that f_d^* is substituted for f^* and $k = 0.43$.

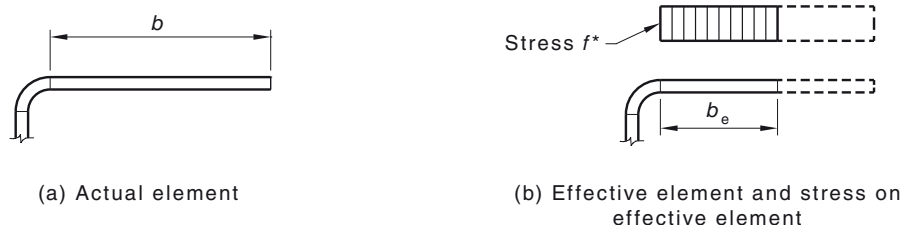


FIGURE 2.3.1 UNSTIFFENED ELEMENT WITH UNIFORM COMPRESSION

2.3.2 Unstiffened elements and edge stiffeners with stress gradient

2.3.2.1 General

For unstiffened elements and edge stiffeners with stress gradient, the effective widths for section or member capacity and deflection calculations shall be determined in accordance with Clauses 2.3.2.2 and 2.3.2.3, respectively.

2.3.2.2 Effective width for capacity calculations

For determining the section or member capacity, the effective widths (b_e) measured from the supported edge of unstiffened compression elements and edge stiffeners with stress gradient shall be determined in accordance with Clause 2.2.1.2, with $f^* = f_1^*$ and with k and ρ determined in accordance with this Clause.

f_1^*, f_2^* = stresses shown in Figures 2.3.2(A) and 2.3.2(B) calculated on the basis of the gross section where f_1^* is compression (+) and f_2^* may be either tension (−) or compression (+). In the case where f_1^* and f_2^* are both in compression $f_1^* \geq f_2^*$

ψ = stress ratio
 $= f_2^* / f_1^*$. . . 2.3.2.2(1)

The effective width factor (ρ) and the plate buckling coefficient (k) shall be determined as follows:

- (a) For unstiffened elements with stress gradient causing compression at both longitudinal edges of the unstiffened element (f_1^* and f_2^*) both in compression, as shown in Figure 2.3.2(A).

ρ shall be determined using Equation 2.2.1.2(3) and λ shall be determined using Equation 2.2.1.2(4). The buckling coefficient (k) in Equation 2.2.1.2(5) shall be determined as follows:

- (i) Where the stress decreases toward the unstiffened edge of the element as shown in Figure 2.3.2(A)(i), k shall be calculated as follows:

$$k = \frac{0.578}{\psi + 0.344} \quad \dots 2.3.2.2(2)$$

- (ii) Where the stress increases toward the unstiffened edge of the element as shown in Figure 2.3.2(A)(ii), k shall be calculated as follows:

$$k = 0.57 - 0.21\psi + 0.07\psi^2 \quad \dots 2.3.2.2(3)$$

- (b) For unstiffened elements with stress gradient causing compression at one longitudinal edge and tension at the other longitudinal edge of the unstiffened element:

- (i) For f_1^* in compression at the unsupported edge and f_2^* in tension as shown in Figure 2.3.2(B)(i), ρ shall be calculated as follows:

$$\rho = 1 \quad \text{for } \lambda \leq 0.673(1 - \psi)$$

$$\rho = (1 - \psi) \frac{1 - \frac{0.22(1 - \psi)}{\lambda}}{\lambda} \quad \text{for } \lambda > 0.673(1 - \psi) \quad \dots 2.3.2.2(4)$$

λ shall be determined using Equation 2.2.1.2(4).

$$k = 0.57 - 0.21\psi + 0.07\psi^2 \quad \dots 2.3.2.2(5)$$

- (ii) For f_1^* in compression at the supported edge and f_2^* in tension as shown in Figure 2.3.2(B)(ii), ρ shall be calculated as follows:

$$\text{For } -1 < \psi < 0: \quad \rho = 1 \quad \text{for } \lambda \leq 0.673$$

$$\rho = (1 + \psi) \frac{\left(1 - \frac{0.22}{\lambda}\right)}{\lambda} - \psi \quad \text{for } \lambda > 0.673 \quad \dots 2.3.2.2(6)$$

λ shall be determined using Equation 2.2.1.2(4).

$$k = 1.70 - 5\psi + 17.1\psi^2 \quad \dots 2.3.2.2(7)$$

$$\text{For } \psi \leq -1: \quad \rho = 1$$

Alternatively, the plate buckling coefficient (k) in Equation 2.3.2.2(5) may be determined using Equation 2.3.2.2(8) for plain channels bent in the plane of symmetry with the unsupported edge of the unstiffened element in compression as follows:

$$k = 0.1451(b_2/b_1) + 1.256 \quad \dots 2.3.2.2(8)$$

where

b_2 = width of the unstiffened element

b_1 = width of the stiffened element

For other types of sections, k in Equations 2.3.2.2(2), 2.3.2.2(3), 2.3.2.2(5) and 2.3.2.2(7) for the unstiffened element and k for each remaining flat element of the section may be determined from a rational elastic buckling analysis of the whole section as a plate assemblage subjected to the longitudinal stress distribution in the section prior to buckling.

In calculating the effective section modulus (Z_e) in Clause 3.3.2.2 or in Clause 3.3.3.2, the extreme compression fibre in Figures 2.3.2(A)(ii) and 2.3.2(B)(i) is taken as the edge of the effective section (closer to the unsupported edge).

In calculating the effective section modulus (Z_e) in Clause 3.3.2.2, the extreme tension fibre in Figure 2.3.2(B)(ii) is taken as the edge of the effective section (closer to the unsupported edge).

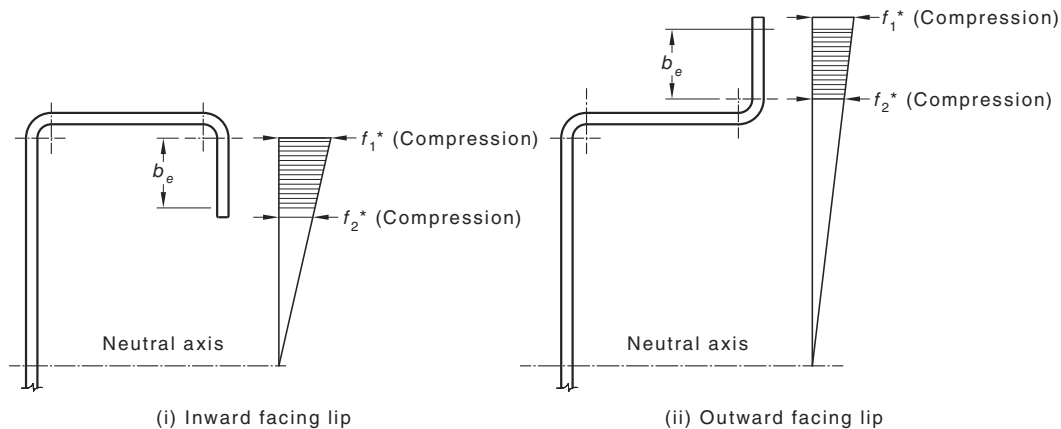


FIGURE 2.3.2(A) UNSTIFFENED ELEMENTS WITH STRESS GRADIENT—
BOTH EDGES IN COMPRESSION

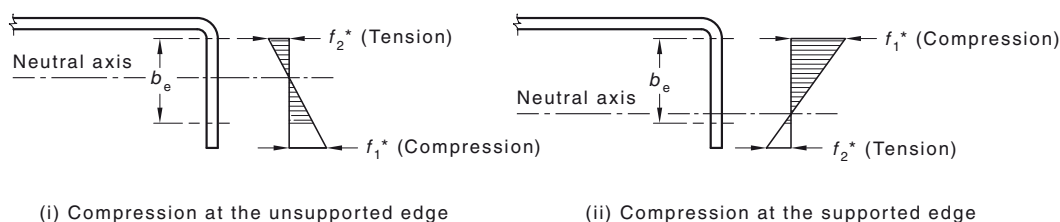


FIGURE 2.3.2(B) UNSTIFFENED ELEMENTS WITH STRESS GRADIENT—
ONE EDGE IN COMPRESSION AND ONE EDGE IN TENSION

2.3.2.3 Effective width for deflection calculations

For determining the deflection, the effective widths (b_e) of unstiffened elements and edge stiffeners with stress gradient shall be determined in accordance with Clause 2.3.2.2 except that f_{d1}^* and f_{d2}^* are substituted for f_1^* and f_2^* . The calculated stresses f_1^* and f_2^* (see Figures 2.3.2(A) and 2.3.2(B)) shall be used to determine f_{d1}^* and f_{d2}^* respectively. Calculations shall be based on the effective section for the load for which deflections are determined.

2.4 EFFECTIVE WIDTHS OF UNIFORMLY COMPRESSED ELEMENTS WITH AN EDGE STIFFENER

2.4.1 General

For uniformly compressed elements with an edge stiffener, the effective widths for section or member capacity and deflection calculations shall be determined in accordance with Clauses 2.4.2 and 2.4.3 respectively.

2.4.2 Effective width for capacity calculations

For determining the section or member capacity, the effective widths (b_e) of uniformly compressed elements with an edge stiffener shall be determined as follows:

$$(a) \quad \frac{b}{t} \leq 0.328S$$

$I_a = 0$ (no edge stiffener is required)

= adequate second moment of area of the stiffener, so that each component element behaves as a stiffened element

$$b_e = b \quad \dots 2.4.2(1)$$

$$b_1 = b_2 = b/2 \quad (\text{see Figure 2.4.2}) \quad \dots 2.4.2(2)$$

$$d_s = d_{sc} \quad (\text{for simple lip stiffener}) \quad \dots 2.4.2(3)$$

$$A_s = A_{sc} \quad (\text{for other stiffener shapes}) \quad \dots 2.4.2(4)$$

$$(b) \quad \frac{b}{t} > 0.328S$$

$$b_1 = \frac{b_e}{2} \left(\frac{I_s}{I_a} \right) \quad (\text{see Figure 2.4.2}) \quad \dots 2.4.2(5)$$

$$b_2 = b_e - b_1 \quad (\text{see Figure 2.4.2}) \quad \dots 2.4.2(6)$$

$$d_s = d_{sc} \left(\frac{I_s}{I_a} \right) \quad (\text{for simple lip stiffener}) \quad \dots 2.4.2(7)$$