

Australian/New Zealand Standard™

Cold-formed stainless steel structures



AS/NZS 4673:2001

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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee BD-086, Stainless Steel Structures.

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

Sections 1, 2, 3, 4 and 5 of this Standard are based on ANSI/ASCE-8-90 Specification for the Design of Cold-formed Stainless Steel Structural Members. Section 6 is based on AS/NZS 4600 and AS/NZS 1664.1.

Statements expressed in mandatory terms in notes to tables are deemed to be requirements 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

Australian/New Zealand Standard
Cold-formed stainless steel structures

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard sets out minimum requirements for the design of stainless steel structural members cold-formed to shape from annealed or temper-rolled sheet, strip, plate or flat bar stainless steels used for load-carrying purposes in buildings. It may also be used for structures other than buildings provided appropriate allowances are made for dynamic effects.

For the purpose of this Standard, steels with at least 10.5% chromium and up to 1.2% carbon are considered as stainless steels.

1.2 REFERENCED DOCUMENTS

The documents referred to in this Standard are listed in Appendix A.

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.

NOTE: In this Standard, terms in square brackets relate to New Zealand use.

1.3.1 Action [Effect]

The cause of stress, dimensional change, or displacement in a structure or a component of a structure.

1.3.2 Action effect [Action] or load effect [action]

The internal force, moment, deformation, crack, or like effect caused by one or more actions [effects].

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(d).)

1.3.4 Bend

Portion adjacent to flat elements and having a maximum inside radius-to-thickness ratio (r_i/t) of 8. (See Figure 1.1.)

1.3.5 Braced member

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

1.3.6 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.

1.3.7 Capacity [Strength reduction] factor

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

1.3.8 Cold-formed stainless 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.

1.3.9 Design action effect [Design action] or design load effect [design action]

The action [effect] or load effect [action] calculated from the design actions [design forces] or design loads.

1.3.10 Design action [Design force] or design load

The combination of the nominal actions [nominal effects] or loads and the load factors, as specified in the relevant loading Standard.

1.3.11 Design capacity

The product of the nominal capacity and the capacity [strength reduction] factor.

1.3.12 Effective design width

Where the flat width of an element is reduced for design purposes, the reduced design width is termed the effective width or effective design width.

1.3.13 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 1.2.)
- (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 1.2.)
- (c) Arched elements—circular or parabolic elements having the inside radius-to-thickness ratio greater than eight ($r_i/t > 8$). (See Figure 1.2.)

1.3.14 Feed width (w_f)

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

1.3.15 Flat-width-to-thickness ratio

The flat width of an element measured along its plane, divided by its thickness.

1.3.16 Flexural-torsional buckling

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

1.3.17 Initial Young's modulus

The initial slope of the stress-strain curve. (See Appendix B.)

1.3.18 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.

1.3.19 Limit state

A state beyond which the structure no longer satisfies the design performance requirements.

NOTE: Limit states separate desired states [no failure] from undesired states [failure].

1.3.19.1 Limit state, serviceability

A state that corresponds to conditions beyond which specified service requirements for a structure or structural element are no longer met.

NOTE: Requirements are based on the intended use and may include limits on deformation, vibratory response, degradation or other physical aspects.

1.3.19.2 Limit state, stability

A limit state corresponding to the loss of static equilibrium of a structure considered as a rigid body.

NOTE: In New Zealand, the stability limit state is part of the ultimate limit state.

1.3.19.3 Limit state, ultimate

A state 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.

1.3.20 Load

An externally applied limit state force including self-weight.

1.3.21 Local buckling

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

1.3.22 May

Indicates the existence of an option.

1.3.23 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).)

1.3.24 Nominal action [Nominal effect] or nominal load

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

1.3.25 Nominal capacity

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

1.3.26 Point-symmetric section

A section symmetrical about a point (centroid) such as a Z-section having equal flanges. (See Figure 1.5(b).)

1.3.27 Proof stress

The stress at a nominated plastic strain. (See Appendix B.)

1.3.28 Proof testing

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

1.3.29 Prototype testing

The 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 that are nominally identical to the units tested.

1.3.30 Segment (in a member subjected to bending)

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

1.3.31 Secant modulus

The slope of a line from the origin to a point on the stress-strain curve. (See Appendix B.)

1.3.32 Shall

Indicates that a statement is mandatory.

1.3.33 Should

Indicates a recommendation.

1.3.34 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.

1.3.35 Stiffened or partially stiffened compression element

A flat compression element (i.e. 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).)

1.3.36 Stiffener(s)**1.3.36.1 Edge stiffener**

Formed element at the edge of a flat compression element. (See Figure 1.4(a).)

1.3.36.2 Intermediate stiffeners

Formed elements, employed in multiple stiffened segments, and located between edges of stiffened elements. (See Figure 1.4(b).)

1.3.37 Structural ductility factor

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

1.3.38 Structural performance factor

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

1.3.39 Structural response factor

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

1.3.40 Sub-element

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

1.3.41 Tangent modulus

The slope tangential to the stress-strain curve. (See Appendix B.)

1.3.42 Temper rolling

Cold-working of annealed stainless steel by rolling to achieve increased strength.

1.3.43 Tensile strength

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

1.3.44 Thickness

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

1.3.45 Unformed steel

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

1.3.46 Unformed steel properties

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

1.3.47 Unstiffened compression element

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

1.3.48 Yield stress

In the absence of a yield plateau, the yield stress is taken as the 0.2% proof stress, which is the stress at 0.2% plastic strain. (See Appendix B.)

NOTE: The yield stress varies with the rolling direction, transverse or longitudinal, and is different in tension and compression.

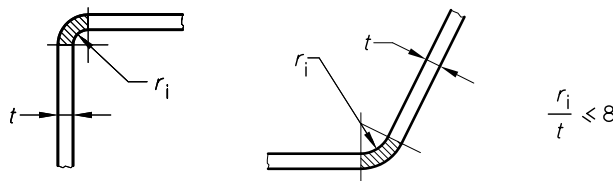
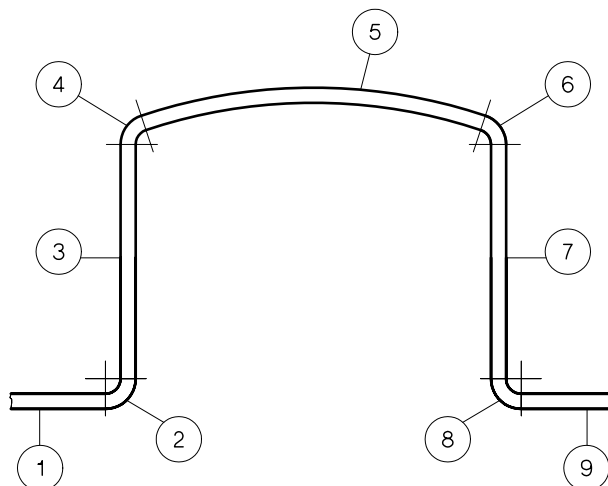


FIGURE 1.1 BENDS



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 1.2 ELEMENTS

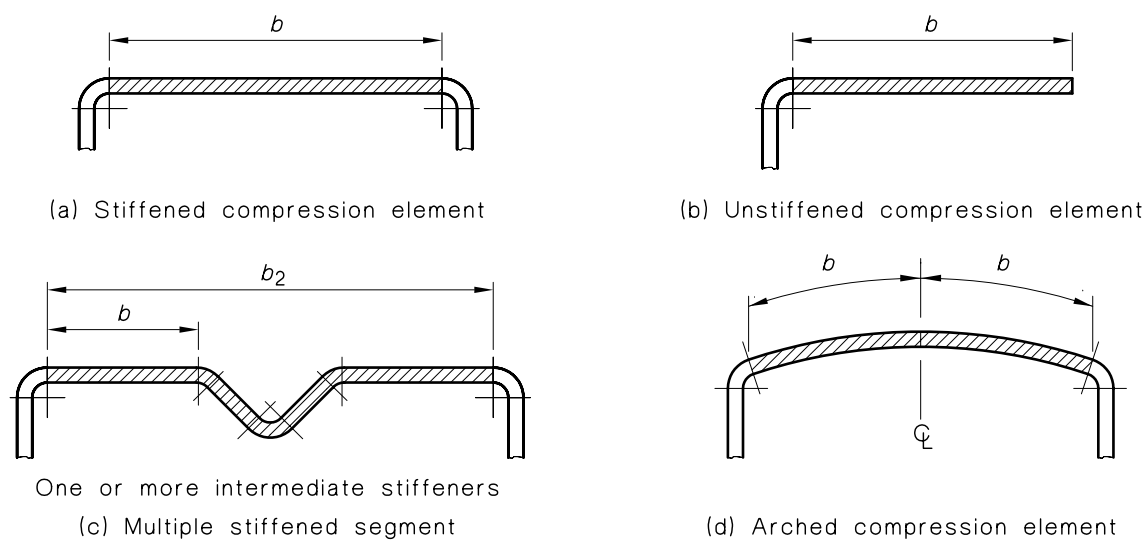


FIGURE 1.3 STIFFENING MODES

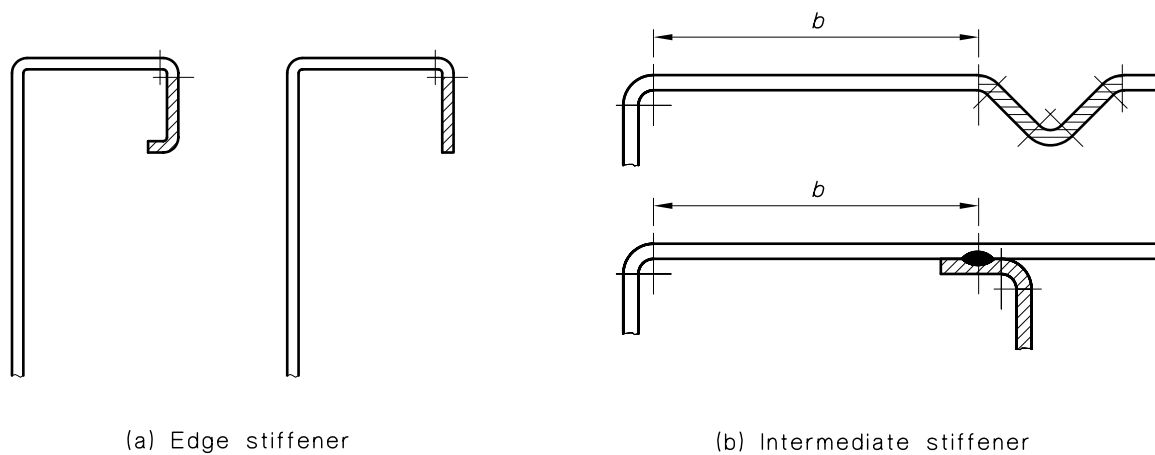


FIGURE 1.4 STIFFENERS

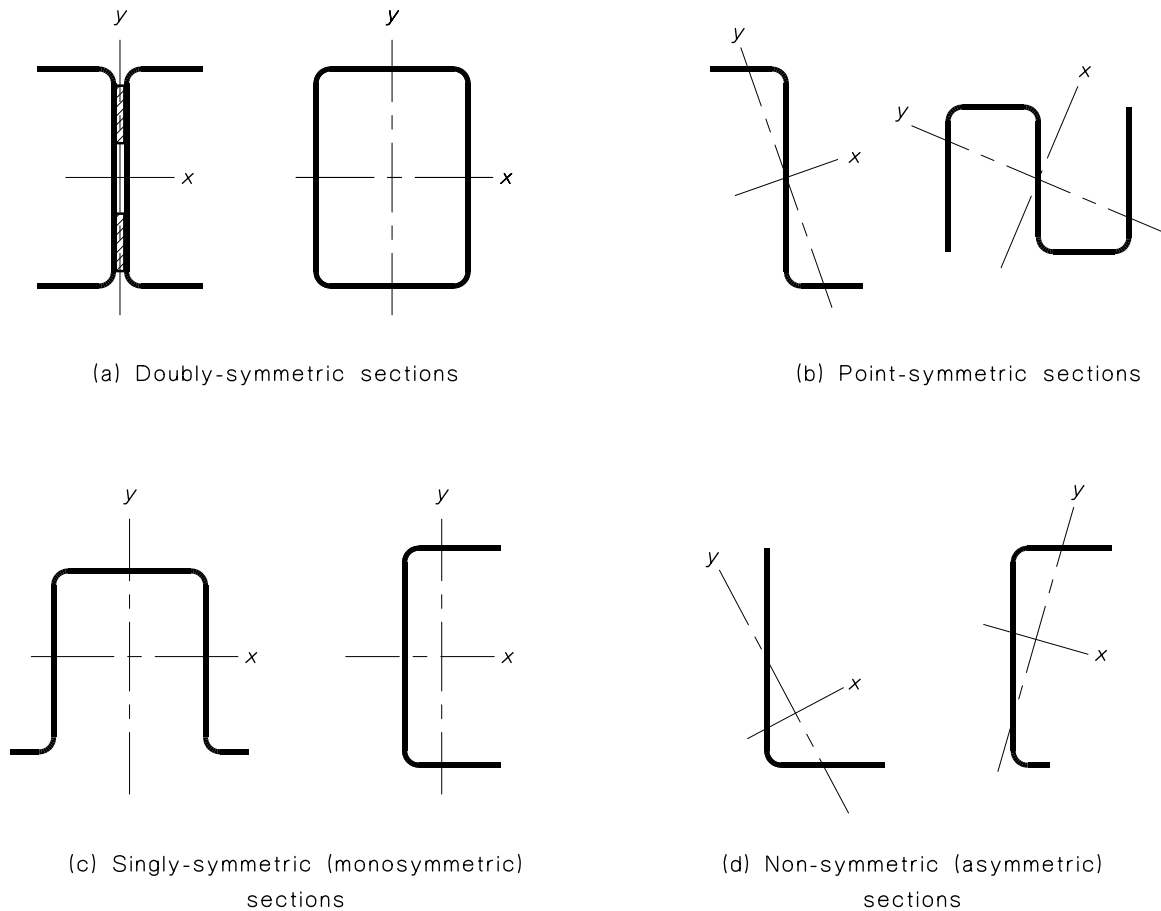


FIGURE 1.5 EXAMPLES OF SECTION SYMMETRY

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 [design action] due to the design load for the strength [ultimate] limit state.

TABLE 1.4
NOTATION

Symbol	Description	Clause reference
A	area of the full, unreduced cross-section; <i>or</i> gross cross-sectional area of a channel or Z-section	3.3.3
A_b	gross cross-sectional area of the bolt	5.3.8.2
A_{bs}	tensile stress area of the bolt	5.3.8.2
A_e	effective area calculated at buckling stress f_n	3.4.1
A_{ef}	effective area of edge stiffener or intermediate stiffeners	2.5
A_f	gross cross-sectional area of the stainless steel bolt	5.3.7.2
A_n	net area of the cross-section; <i>or</i> net area of the connected part at the line of bolts transverse to the line of the applied force	3.2, 5.3.5
A_o	reduced area of the cross-section	3.6.3
A_s	reduced area of a stiffener; <i>or</i> cross-sectional area of a transverse stiffener	2.4.1, 2.6.1
A_{se}	effective area of a stiffener	2.4.1
A_{st}	gross area of a shear stiffener	2.6.2
A_{s1}, A_{s2}	area of a member in compression consisting of the transverse stiffeners and a portion of the web	2.6.1
a	distance between transverse stiffeners	2.6.2
B_c	constant	1.5.2.4
b	flat width of element excluding radii; <i>or</i> flat width of the compression flange	2.2.1.2, 2.4.1, 3.6.2
b_e	effective width of uniformly compressed stiffened and unstiffened elements used for determining the load capacity [strength]	2.2.1.2, 2.3.1.2, 2.3.1.3
b_{ed}	effective width of uniformly compressed stiffened and unstiffened elements used for determining the deflection	2.2.1.3, 2.3.2.3
b_{es}	effective width of a sub-element or element to be used in design calculations	2.5
b_{e1}, b_{e2}	effective width of uniformly compressed stiffened element with stress gradient	2.2.2.1, 2.2.2.2
b_f	flat width of the beam flange that contacts the bearing plate	3.3.7
b_1	width of the compression and tension flanges, either stiffened or unstiffened, projecting beyond the web for I-beams and similar sections; <i>or</i> maximum 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> flat width of the narrowest unstiffened compression element tributary to the connections	2.1.3.2, 2.1.3.3, 4.1.2
b_2	flat width of element with intermediate stiffener excluding radii	2.4.1

(continued)

TABLE 1.4 (continued)

Symbol	Description	Clause reference
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> ratio of the proportionality stress to the yield stress	1.5.2.4, 3.6.2
C_b	bending coefficient	3.3.3
C_m	coefficient for unequal end moment	3.5
C_s	coefficient for moment causing compression or tension on the shear centre side of the centroid	3.3.3
C_y	compression strain factor	3.3.2.3
C_w	torsional warping constant of the cross-section	3.3.3
C_1 to C_{11} , and C_θ	coefficient	2.4.1, 3.3.6
c_f	amount of curling	2.1.3.2
d	depth of a section; <i>or</i> actual stiffener dimension	2.1.3.2, 2.4.1
d_f	nominal diameter of a bolt	5.3.2
d_h	standard hole diameter	5.3.2
d_l	depth of the flat portion of the web measured along the plane of the web; <i>or</i> actual stiffener dimension	2.1.3.4, 2.4.1
d_m	mean of the across points and across flats dimensions of the bolt head or the nut, whichever is smaller	5.3.8.3
d_o	outside diameter of a chord	Paragraph J3
d_s	reduced effective width of a stiffener; <i>or</i> effective stiffener dimension	2.4.1
d_{se}	effective width of a stiffener	2.4.1
d_w	depth of the compressed portion of the web	3.3.2.3
d_1	depth of the flat portion of a web measured along the plane of the web	2.1.3.4
E_o	Initial Young's modulus of elasticity	1.3.17
E_r	reduced modulus of elasticity	2.2.1.3
E_s	secant modulus for normal stress	Paragraph B1
E_{sc}	secant modulus corresponding to stress in compression flange	2.2.1.3
E_{st}	secant modulus corresponding to stress in tension flange	2.2.1.3
E_t	tangent modulus in compression; <i>or</i> tangent modulus for normal stress	3.4.2, Paragraph B1
e	distance measured in the line of the applied 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> eccentricity	5.3.3, Paragraph J3
e_y	yield strain	3.3.2.3

(continued)

TABLE 1.4 (continued)

Symbol	Description	Clause reference
f	normal engineering stress	Paragraph B1
f_b	permissible compressive stress for local distortion	3.3.2.4
f_c	stress at service load in the cover plate or sheet	4.1.2
f_{cr}	critical buckling stress	3.3.2.4
f_n	buckling stress	2.6.1
f'_{nt}	nominal tensile strength for bolts subject to combined shear and tension	5.3.7.4
f_{nt}	nominal tensile strength of the stainless steel bolt	5.3.8.3
f_{nv}	nominal shear strength of the stainless steel bolt	5.3.7.2
f_{oc}	flexural buckling stress	3.4.2
f_{pc}	offset proportional limit in compression	Paragraph B1
f_t	tensile strength for connections with washers under bolt, bolt head and nut	5.3.5
f_u	minimum tensile strength used in the design; <i>or</i> tensile or compressive strength of the connected part in the direction of the applied force	1.5.2.2, 5.3.5, 5.3.6
f_{ua}	tensile or compressive strength of the annealed base metal	5.2.2.2
f_{ut}	tensile strength of the connected part transverse to the direction of the applied force	5.3.4
f_{uv}	tensile strength of unformed steel	1.5.2.4
f_v	shear stress resulting from the design shear force	5.3.7.4
f_{wy}	lower yield stress value of a beam web (f_y) or of a stiffener section (f_{ys})	2.6.1
f_{xx}	tensile strength obtained from all-weld-metal tensile test	5.2.3.2
f_y	minimum tensile or compressive yield stress used in design; <i>or</i> yield stress of web steel; <i>or</i> yield stress of stiffener; <i>or</i> specified yield stress in longitudinal compression or tensile strength of the connected part in the direction of the applied force; <i>or</i> offset yield stress in compression	1.5.2.2, 5.3.5, Paragraph B1
f_{ya}	average design yield stress of the steel in the full section of compression members or full flange sections of flexural members	1.5.2.4
f_{yc}	tensile yield stress of bends; <i>or</i> compressive yield stress	1.5.2.4, 6.1.4
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	1.5.2.4, 6.1.5.1
f_{ys}	yield stress of stiffener steel	2.6.1
f_{yt}	minimum tensile yield stress	1.5.3
f_{yv}	tensile yield stress of unformed steel; <i>or</i> specified shear yield stress	1.5.2.4, Appendix B
f^*	design stress in the compression element calculated on the basis of the effective design width	2.2.1.2

(continued)

TABLE 1.4 (continued)

Symbol	Description	Clause reference
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
f_1^*, f_2^*	web stresses calculated on the basis of the effective section or on the full section	2.2.2.1
f_3^*	stress in edge stiffener with stress gradient for which load capacities are determined	2.3.2.2
G_o	initial shear modulus	3.3.3
G_s	secant modulus for shear stress	Paragraph B1
G_t	tangent modulus for shear stress	Paragraph B1
g	distance measured along the length of the connected face of the chord, between the toes of the adjacent members	Paragraph J2.1
h_o	depth of the chord in the plane of the lattice girder	Paragraph J3
I_a	adequate second moment of area of a stiffener, so that each component element behaves as a stiffened element	2.4.1
I_b	second moment of area of the full, unreduced cross-section about the bending axis	3.5
I_s	second moment of area of a full stiffener about its own centroidal axis parallel to the element to be stiffened	2.4.1
I_{st}	second moment of area of the full area of a multiple-stiffened element, including the intermediate stiffeners, about its own centroidal axis	2.5
I_w	warping constant for a cross-section	Paragraph H1
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 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	3.3.3
J	St. Venant torsion constant of the cross-section	3.3.3
k	plate buckling coefficient; <i>or</i> effective length factor	2.2.1.2, 3.4.2
k_f	total population variation due to fabrication	6.2.2.3
k_m	total population of variation due to material	6.2.2.3
k_s	shear stiffener coefficient	2.6.2
k_{sc}	coefficient of variation of structural characteristic	6.2.2.3
k_{st}	stiffener type coefficient	2.6.2
k_t	effective length factor for twisting; <i>or</i> factor to allow for variability of structural units	3.3.3, 6.2.2.2
k_v	shear buckling coefficient	2.6.2
k_x, k_y	effective length factors for bending about the x- and y-axes, respectively	3.3.3

(continued)

TABLE 1.4 (continued)

Symbol	Description	Clause reference
k'	coefficient used to determine N_{ib}^* where neither flange is connected to the sheeting or connected to the sheeting with concealed fasteners	4.3.3.3
l	actual length of an axially loaded compression member; <i>or</i> unbraced length of a member in compression	1.3.18, 3.3.3
l_b	actual length of bearing	3.3.6
l_{eb}	effective length in the plane of bending	3.5
l_{st}	length of transverse stiffener	2.6.1
l_t	unbraced length of the compression member for twisting	3.3.3
l_w	length of the full size of the weld	5.2.2.3
l_x, l_y	unbraced lengths of the compression member for bending about the x - and y -axes, respectively	3.3.3
M_b	nominal member moment capacity	2.2.1.2
M_{bx}, M_{by}	nominal member moment capacities about the x - and y - axes, respectively	3.5
M_c	critical moment	3.3.3
M_{ld}	nominal flexural capacity of the member	3.3.2.4
M_m	mean value of the measured yield stress to the nominal yield stress of the finished product	Appendix K
$M_{max.}$	absolute value of the maximum moment in the unbraced segment	3.3.3
M_s	nominal section moment capacity	2.2.1.2
M_y	moment causing initial yield	2.2.1.2
M_3	absolute value of the moment at quarter point of the unbraced segment	3.3.3
M_4	absolute value of the moment at centre-line of the unbraced segment	3.3.3
M_5	absolute value of the moment at three-quarter point of the unbraced segment	3.3.3
M^*	design bending moment	3.3.1
M_x^*, M_y^*	design bending moment about the x - and y -axes, respectively	3.5
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	1.5.2.4, 3.3.6, 4.1.1, 4.3.3.3
N_c	nominal member capacity of a member in compression	2.6.1
N_e	elastic buckling load	3.5
N_f	nominal tensile capacity of the connected part	5.3.5
N_s	nominal section capacity of a member in compression	2.6.1
N_t	nominal section capacity of a member in tension	3.2
N_w	nominal tensile or compressive capacity of a butt weld or a resistance spot weld, welded from one or both sides	5.2.1.2, 5.2.3.3
N^*	design concentrated load or reaction; <i>or</i> design axial force, tensile or compressive	2.6.1, 3.4.1

(continued)

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TABLE 1.4 (continued)

Symbol	Description	Clause reference
N_f^*	design tensile force in the connected part	5.3.5
N_{ft}^*	design tensile force on a bolt	5.3.7.4
N_{ib}^*	design force to be resisted by intermediate beam brace	4.3.3.3
N_w^*	design tensile or compressive force normal to the area of a butt weld or on a resistance spot weld	5.2.2.2, 5.2.4.3
n	constant	Paragraph B1
q	intensity of the design load on a beam	4.1.1
R_b	nominal capacity for concentrated load or reaction for one solid web connecting top and bottom flanges; <i>or</i> nominal capacity for concentrated load or reaction in the absence of bending moment	3.3.6, 3.3.7
R_d	design capacity of members and connections	1.6.2.2, 6.2.2.7
R_f	structural response factor	1.6.3
$R_{min.}$	minimum value of the test results	6.2.2.7
R_t	target test loads for the number of units to be tested	6.2.2.2
R_u	nominal capacity of members and connections	1.6.2.2
R^*	design concentrated load or reaction in the presence of bending moment	3.3.7
R_b^*	design concentrated load or reaction	3.3.6
r	radius of gyration of the full, unreduced cross-section	3.4.2
r_{cy}	radius of gyration of one channel about its centroidal axis parallel to the web	4.1.1
r_f	ratio of the force transmitted by the bolt or bolts at the section considered, divided by the tensile force in the member at that section	5.3.5
r_i	inside bend radius	1.3.4
r_o	polar radius of gyration of the cross-section about the shear centre	3.3.3
r_x, r_y	radii of gyration of the cross-section about the centroidal axes	3.3.3
r_1	radius of gyration of an 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	2.4.1
S_p	structural performance factor; <i>or</i> plastic section modulus	1.6.3, 3.6.2
S^*	design action effects [design actions]	1.6.2.2
s	spacing in line of the stress of welds and bolts, connecting a cover plate or sheet in compression, to a non-integral stiffener or another element	4.1.2
s_f	spacing of bolts transverse to the line of the force; <i>or</i> width of the connected part, in the case of a single bolt	5.3.5
s_g	vertical distance between two rows of connections nearest to the top and bottom flanges	4.1.1
$s_{max.}$	maximum longitudinal spacing of welds or other connectors joining two channels to form an I-section	4.1.1

(continued)



TABLE 1.4 (continued)

Symbol	Description	Clause reference
s_w	weld spacing	4.1.1
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 the thinnest welded part; <i>or</i> thickness of the thinnest connected part	1.5.2.8, 2.1.3.1, 2.2.1.2, 2.6.1, 5.2.2.2, 5.3.4
t_f	thickness of the flange	2.1.3.2
t_p	thickness of the plate under the bolt head or the nut	5.3.8.3
t_s	thickness of the stiffener steel	2.5
t_w	thickness of a web; <i>or</i> effective throat	2.1.3.4, 5.2.3.2
V_b	nominal bearing capacity per bolt of the connected part, where bolts have washers under both bolt head and nut	5.3.6
V_f	nominal shear capacity per bolt	5.3.4
V_{fv}	nominal shear capacity of a stainless steel bolt	5.3.7.2
V_M	coefficient of variation of the ratio of the measured yield stress to the nominal yield stress of the finished product	Appendix K
V_v	nominal shear capacity of the beam	3.3.4
V_w	nominal shear capacity of a butt, fillet, or resistance weld, welded from one or both sides; <i>or</i> nominal shear force transmitted by the weld	5.2.2.3, 5.2.3.2, 5.2.3.3, 5.2.4.2
V^*	design shear force	3.3.2.3
V_b^*	design bearing force at a bolt	5.3.6
V_f^*	design shear force per bolt	5.3.4
V_{fv}^*	design shear force for bolts loaded in shear	5.3.7.2
V_w^*	design shear force on a butt, fillet or resistance weld; <i>or</i> design longitudinal or transverse shear force on a fillet weld	5.2.2.3, 5.2.3.2, 5.2.3.3, 5.2.4.2
w_1, w_2	leg sizes of the weld	5.2.3.2
x_o	distance from the shear centre of the cross-section to the centroid along the principal x-axis, taken as negative	3.3.3
Z_c	elastic section modulus of the effective section calculated at a stress M_c/Z_f in the extreme compression fibre	3.3.3
Z_e	effective section modulus calculated with the extreme compression or tension fibre at f_{yc} or f_{yt} , respectively, whichever initiates yield	3.3.2.2
Z_f	elastic section modulus of the full, unreduced cross-section	3.3.2.4
α	reduction factor	2.5
α_{nx}, α_{ny}	moment amplification factor	3.5
ϵ	normal strain	Paragraph B1
ϵ_y	offset yield strain	Paragraph B1
ϵ_p	offset proportional limit strain	Paragraph B1
η	plasticity buckling stress	3.3.2.4

(continued)

TABLE 1.4 (continued)

Symbol	Description	Clause reference
θ	angle between the plane of the web and the plane of the bearing surface	3.3.6
λ_{ov}	overlap	Paragraph J2.3
$\lambda, \lambda_1, \lambda_2$	slenderness ratio	2.2.1.2, 3.3.2.3
μ	structural ductility factor	1.6.3
ν	Poisson's ratio in elastic range of 0.3	3.3.2.4
ρ	quantity for load capacity [strength]; or effective width factor	1.5.2.4, 2.2.1.2
ϕ	capacity [strength reduction] factor	1.6.2.2
ϕ_b	capacity [strength reduction] factor for bending	3.3.1
ϕ_c	capacity [strength reduction] factor for members in compression	2.6.1
ϕ_d	capacity [strength reduction] factor for local distortion	3.3.2.4
ϕ_o	reference value	Appendix K
ϕ_t	capacity [strength reduction] factor for members in tension	3.2
ϕ_v	capacity [strength reduction] factor for shear	3.3.5
ϕ_w	capacity [strength reduction] factor for bearing	3.3.6
ψ	stress ratio f_2^* / f_1^*	2.2.2.1

1.5 MATERIALS

1.5.1 Selection of stainless steel grade

1.5.1.1 Factors to be considered

The selection of the most appropriate grade of stainless steel shall take into account the mechanical properties, effect of welding on mechanical properties and corrosion resistance, the environment of the application, the surface finish and appearance, and the maintenance of the structure. Detailed consideration needs to be given to design for corrosion resistance when a material is selected for use in a corrosive environment.

1.5.1.2 Corrosion resistance

An appropriate grade of stainless steel shall be selected in accordance with the corrosion resistance required for the environment in which the structural members are to be used and in accordance with the fabrication, strength and finish requirements for the specific application.

NOTE: For initial guidance on grade selection for corrosion resistance, see Appendix C.

1.5.1.3 Surface finish and appearance

Consideration shall be given to restitution of the surface after fabrication, and to maintenance during service.

NOTE: A variety of surface finishes is described in Appendix C.

1.5.1.4 Cosmetic applications

In cosmetic applications, the possible minor changes in surface appearance that might take place as a result of dirt deposits, which in adverse circumstances can create crevices and lead to surface micro-pitting, shall also be taken into account. A suitable corrosion-resistant grade of stainless steel shall be used to ensure that only superficial surface attack takes place within the design life of the component.

1.5.1.5 Maintenance

If necessary, a suitable cleaning regime shall be specified to maintain the surface appearance.

1.5.2 Stainless steels

1.5.2.1 Applicable stainless steel grades

Structural members or steel used in manufacturing shall comply with AS 1449, ASTM A167, ASTM A176, ASTM A240, ASTM A276, ASTM A480, ASTM A666, EN 10088 and JIS G4305, as applicable.

1.5.2.2 Other stainless steel grades

Clause 1.5.2.1 shall not be interpreted to exclude the use of other steels, the properties and suitability of which shall be determined in accordance with Clause 1.5.2.6. The yield stress (f_y) and tensile strength (f_u) used in design shall be determined in accordance with Section 6. The steel shall conform to the chemical and other mechanical requirements, and shall have been subjected by either the producer or purchaser to analyses, tests and other controls as prescribed by one of the Standards listed in Clause 1.5.2.1 or in accordance with Clause 1.5.2.6.

1.5.2.3 Availability of stainless steel grades and product forms

Not all grades are readily available in all product forms. Appendix C describes the commonly available grades and tempers of stainless steel by product form.

1.5.2.4 Strength increase resulting from cold-forming (ferritic stainless steels)

The increase in yield stress due to cold-forming or temper-rolling, or both, may be partly or completely lost by processes such as welding, annealing or other heat treatment carried out after forming (see Clause 1.5.2.5).

The equations given in this Clause are only applicable to the ferritic stainless steels type 409, type 430, type 439 and to type 1.4003 (EN 10088) steel. The increase in strength due to cold forming for the austenitic stainless steels type 201, type 301, type 304 or type 316, shall be determined by a rational method or by tests.

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 [strength] 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 6).
- (ii) Stub column tests (see Section 6).
- (iii) Calculated as follows:

$$f_{ya} = C f_{yc} + (1 - C) f_{yf} \quad \dots 1.5.2.4(1)$$

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

$$= \frac{B_c f_{yv}}{(r_i/t)^m} \quad \dots 1.5.2.4(2)$$

Equation 1.5.2.4(2) is applicable only if—

(A) f_{uv}/f_{yv} is greater than or equal to 1.2;

(B) r_i/t is less than or equal to 7; and

(C) the minimum included angle is less than or equal to 120°.

B_c = constant

$$= 1.486 \left(\frac{f_{uv}}{f_{yv}} \right) - 0.210 \left(\frac{f_{uv}}{f_{yv}} \right)^2 - 0.128 \quad \dots 1.5.2.4(3)$$

f_{yv} = tensile yield stress of unformed steel

r_i = inside bend radius

m = constant

$$= 0.123 \left(\frac{f_{uv}}{f_{yv}} \right) - 0.068 \quad \dots 1.5.2.4(4)$$

f_{uv} = tensile strength of unformed steel

f_{yf} = yield stress of the flat portions (see Clause 6.1.5); 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). The value of C shall be calculated as for compression members.

1.5.2.5 Effect of welding and heat treatment

The increase in yield stress due to cold-forming or temper-rolling, or both, may be partly or completely lost by processes such as welding, annealing or other heat treatment carried out after forming.

The effect of any welding and heat treatment 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. In the absence of specified testing, the annealed properties shall be used.

Surface finishing of the weld is normally required to restore full corrosion resistance. Surface finishing shall be in accordance with AS/NZS 1554.6.

NOTE: For initial guidance on the effect of welding and heat treatment, see Appendix C.

1.5.2.6 Ductility

Stainless steels not specifically conforming to the Standards listed in Clause 1.5.2.1 shall comply with one of the following requirements:

- (a) The ratio of tensile strength to yield stress in both longitudinal and transverse directions shall be not less than 1.08.
- (b) The total elongation shall be not less than 10% for a 50 mm gauge length, or 7% for a 200 mm gauge length.
- (c) The elongation shall be determined in accordance with Section 6.

1.5.2.7 Acceptance of steels

Certified mill test reports, or test certificates issued by the mill, shall constitute sufficient evidence of compliance with the Standards referred to in this Standard.

1.5.2.8 Delivered minimum thickness

The minimum thickness of the cold-formed stainless steel product in the structure shall not at any location be less than 95% of the thickness (t) used in its design, except at bends and corners where the thickness may be less due to cold-forming effects.

1.5.2.9 Unidentified steel

Unidentified steel may only be used when sufficient samples have been subjected by either the producer or purchaser to analyses, tests and other controls as prescribed by one of the Standards listed in Clause 1.5.2.1 or in accordance with Clause 1.5.2.6.

1.5.3 Design stresses

The minimum yield stress (f_y) used in design shall be the proof stress determined at a plastic strain of 0.2%. The minimum tensile yield stress (f_{yt}) or compressive yield stress (f_{yc}), and tensile strength (f_u) used in design shall not be greater than the higher of the following:

- (a) The specified minimum values given in the Standards listed in Clause 1.5.2.1.
- (b) The values given in Appendix B.
- (c) The values determined by tests in accordance with Section 6.

1.5.4 Fasteners

1.5.4.1 Bolts, nuts and washers

Bolts, nuts and washers complying with ASTM A 193, ASTM A 276, ASTM F 593 or ISO 3506 may be used. A manufacturer's test report, test certificate or letter of conformance, shall constitute sufficient evidence of compliance with the Standard used.

NOTE: Appendix D describes the commonly available grades and tempers of stainless steel fasteners.

1.5.4.2 Welding consumables

All welding consumables shall comply with AS/NZS 1554.6.

1.6 DESIGN REQUIREMENTS

1.6.1 Loads and load combinations

A structure and its components shall be designed for the loads and load combinations as specified in the appropriate limit state loading Standard.

1.6.2 Structural analysis and design

NOTE: Guidance on the applicability of elastic structural analysis to continuous beams and frames is given in Appendix E.

1.6.2.1 General

The following types of limit states shall be considered for the design of structures and its components:

- (a) The ultimate and stability limit states.
- (b) The serviceability limit state.

1.6.2.2 Ultimate limit state

The structure and its component members and connections shall be designed for the ultimate limit state as follows:

- (a) All members and connections shall be proportioned so that the design capacity (R_d) is not less than the design action effect [design action] (S^*), i.e.—

$$S^* \leq R_d$$

- (b) The design action effects [design actions] (S^*) resulting from the ultimate limit state design loads shall be determined by an elastic structural analysis unless—
 - (i) member strength is established by testing in accordance with Section 6; or
 - (ii) it is ensured that any plastic hinges have adequate strength and ductility to perform their intended purpose, in which case the forces and moments may be determined by a plastic analysis.
- (c) The design capacity (R_d) shall be determined by either—
 - (i) the nominal capacity (R_u) in accordance with Sections 2 to 5, and the capacity [strength reduction] factor (ϕ), i.e.—

$$R_d = \phi R_u; \text{ or}$$

- (ii) testing in accordance with Section 6.

1.6.2.3 Stability limit state

The structure as a whole (and any part of it) shall be designed to prevent instability due to overturning, uplift or sliding as specified in the appropriate loading Standard.

1.6.2.4 Serviceability limit state

The structure and its components shall be designed for the serviceability limit state by controlling or limiting deflection, vibration, bolt slip and corrosion, as appropriate.

1.6.2.5 Fatigue

NOTE: Guidance on the design of stainless steel structures for fatigue is given in Appendix F.

1.6.2.6 Fire

NOTE: Guidance on the design of stainless steel structures for fire is given in Appendix G.

1.6.3 Earthquake

Where applicable, the following shall be considered for earthquake design:

- (a) *For Australia* All structures shall be designed for the loads and load combinations specified in AS 1170.4. If stainless steel members are used as the primary earthquake resistance element then the structural response factor (R_f) shall be less than or equal to 2.0 unless specified otherwise.
- (b) *For New Zealand* All structures shall be designed for the loads and load combinations specified in NZS 4203 but subject to the following limitations:
 - (i) For the ultimate limit state, the structural ductility factor (μ) shall be less than or equal to 1.25, unless a greater value (but not greater than 4.0) is justified by a special study. The structural ductility factor (μ) depends upon the structural form, the ductility of the material and structural damping characteristics.

- (ii) For the serviceability limit state, the structural ductility factor (μ) shall be equal to 1.0.
- (iii) The structural performance factor (S_p) shall be equal to 0.67, unless a lower value (but not less than 0.4) is determined as appropriate by a special study. The structural performance factor (S_p) depends on the material, form and period of the earthquake resisting system, damping of the structure and the interaction of the structure with the ground.

1.6.4 Durability

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

NOTE: For further information, see Appendix C.

1.7 NON-CONFORMING SHAPES AND CONSTRUCTION

This Standard shall not be interpreted to prevent the use of alternative shapes or constructions not specifically prescribed in this Standard. Such alternatives shall comply with Section 6.

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.

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 the 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) Location of shear centre (see Paragraph H1 of Appendix H).
- (b) Warping constant (see Paragraph H1 of Appendix H).
- (c) Monosymmetry section constant (see Paragraph H2 of Appendix H).

2.1.2.2 Effective section properties

For the design of cold-formed stainless steel members with slender elements, 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 2.4.1(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 2.2.2.
- (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. Where the unstiffened element is subjected to both tension and compression across its width, the lost portion may be taken as set out in Appendix I.
- (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.

2.1.2.4 Effective section for determining deflection

The effective second moment of area used to determine deflection may be obtained in accordance with Clause 2.2.1.3.

2.1.3 Dimensional limits

2.1.3.1 Maximum flange flat-width-to-thickness ratios

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

- (a) For stiffened compression element having one longitudinal edge connected to a web or flange element and the other stiffened by—
 - (i) simple lip 50; and
 - (ii) any other kind of stiffener having $I_s > I_a$ and $d/b < 0.8$ in accordance with Clause 2.4.3 90.
- (b) For stiffened compression element with both longitudinal edges connected to other stiffened elements 400.
- (c) For unstiffened compression element and elements with an edge stiffener having $I_s < I_a$ and $d/b \leq 0.8$ in accordance with Clause 2.4.3 50.

NOTE: Unstiffened compression elements with b/t ratios greater than 30 and stiffened compression elements with b/t ratios greater than 75 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 400 can be used with adequate design capacity [strength] 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:

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

where

t_f = thickness of the flange

d = depth of the section

E_o = initial Young's modulus of elasticity (given in Appendix B)

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

NOTE: l is the 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 complying with Clause 2.6.1—
 - (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, 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 [strength], the effective widths (b_e) of uniformly compressed stiffened elements shall be determined from either one of the following Equations, as appropriate:

$$\text{For } \lambda \leq 0.673 \quad b_e = b \quad \dots 2.2.1.2(1)$$

$$\text{For } \lambda > 0.673 \quad b_e = \rho b \quad \dots 2.2.1.2(2)$$

where

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

ρ = effective width factor

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

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

$$\lambda = \left(\frac{1.052}{\sqrt{k}} \right) \left(\frac{b}{t} \right) \left(\sqrt{\frac{f^*}{E_o}} \right) \quad \dots 2.2.1.2(4)$$

where

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)

t = thickness of the uniformly compressed stiffened elements

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

E_o = initial Young's modulus of elasticity given in Appendix B.

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.

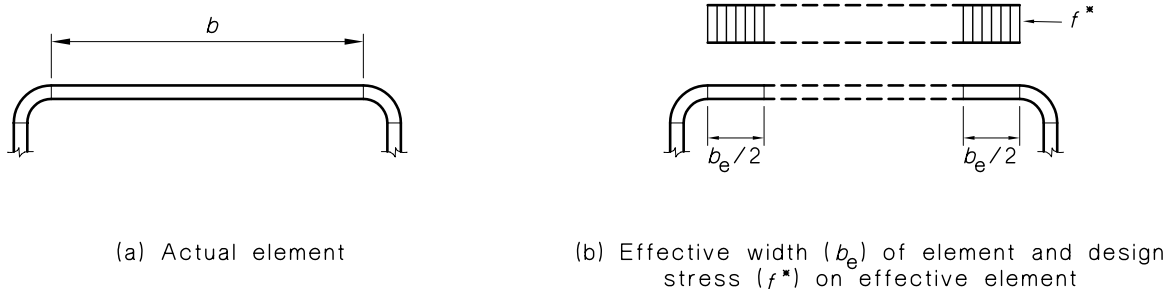


FIGURE 2.2.1 STIFFENED ELEMENTS WITH UNIFORM COMPRESSION

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

- Where 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_{yc} . 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) Where 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 basis of the effective section shall be used to determine M_s .
- (c) Where the nominal member moment capacity (M_b) is based on lateral buckling as specified in Clause 3.3.3, then f^* shall be equal to M_c/Z_f as described in Clause 3.3.3 in determining Z_c .

For compression members, f^* shall be taken equal to f_n determined in accordance with Clause 3.4.

2.2.1.3 Effective width for deflection calculations

For determining the deflection, the effective widths (b_{ed}) shall be determined from either one of the following Equations, as appropriate.

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

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

The effective width factor (ρ) shall be determined from Equations 2.2.1.2(3) and 2.2.1.2(4), except that f_d^* shall be 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, and the reduced modulus of elasticity (E_r) shall be substituted for E_o in Equation 2.2.1.2(4).

$$E_r = \frac{E_{st} + E_{sc}}{2} \quad \dots 2.2.1.3(3)$$

where

E_{st} = secant modulus corresponding to stress in tension flange

E_{sc} = secant modulus corresponding to stress in compression flange

The values of E_{st} and E_{sc} shall be obtained from Appendix B, as appropriate.

2.2.2 Effective widths of webs and stiffened elements with stress gradient

2.2.2.1 Effective widths for capacity calculations

For determining the section or member capacity, the effective width (b_{e1}) (see Figure 2.2.2) shall be determined from the following Equation:

$$b_{e1} = \frac{b_e}{3 - \psi} \quad \dots 2.2.2.1(1)$$

The effective width (b_{e2}) (see Figure 2.2.2) shall be determined from Equation 2.2.2.1(2) or Equation 2.2.2.1(3), as appropriate.

$$\text{For } \psi \leq -0.236: \quad b_{e2} = \frac{b_e}{2} \quad \dots 2.2.2.1(2)$$

where ($b_{e1} + b_{e2}$) shall not be greater than the compression portion of the web calculated on the basis of effective section.

$$\text{For } \psi > -0.236 \quad b_{e2} = b_e - b_{e1} \quad \dots 2.2.2.1(3)$$

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:

$$k = 4 + 2(1 - \psi)^3 + 2(1 - \psi) \quad \dots 2.2.2.1(4)$$

ψ = stress ratio

$$= \frac{f_2^*}{f_1^*} \quad \dots 2.2.2.1(5)$$

f_1^*, f_2^* = web stresses calculated on the basis of the effective section (see Figure 2.2.2)

f_1^* is compression (+) and f_2^* can 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^* .

2.2.2.2 Effective width for deflection calculations

For determining the deflection, the effective widths (b_{e1}) and (b_{e2}) shall be determined in accordance with Clause 2.2.2.1 except that f_{d1}^* and f_{d2}^* shall be substituted for f_1^* and f_2^* . The calculated stresses f_1^* and f_2^* (see Figure 2.2.2) 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.

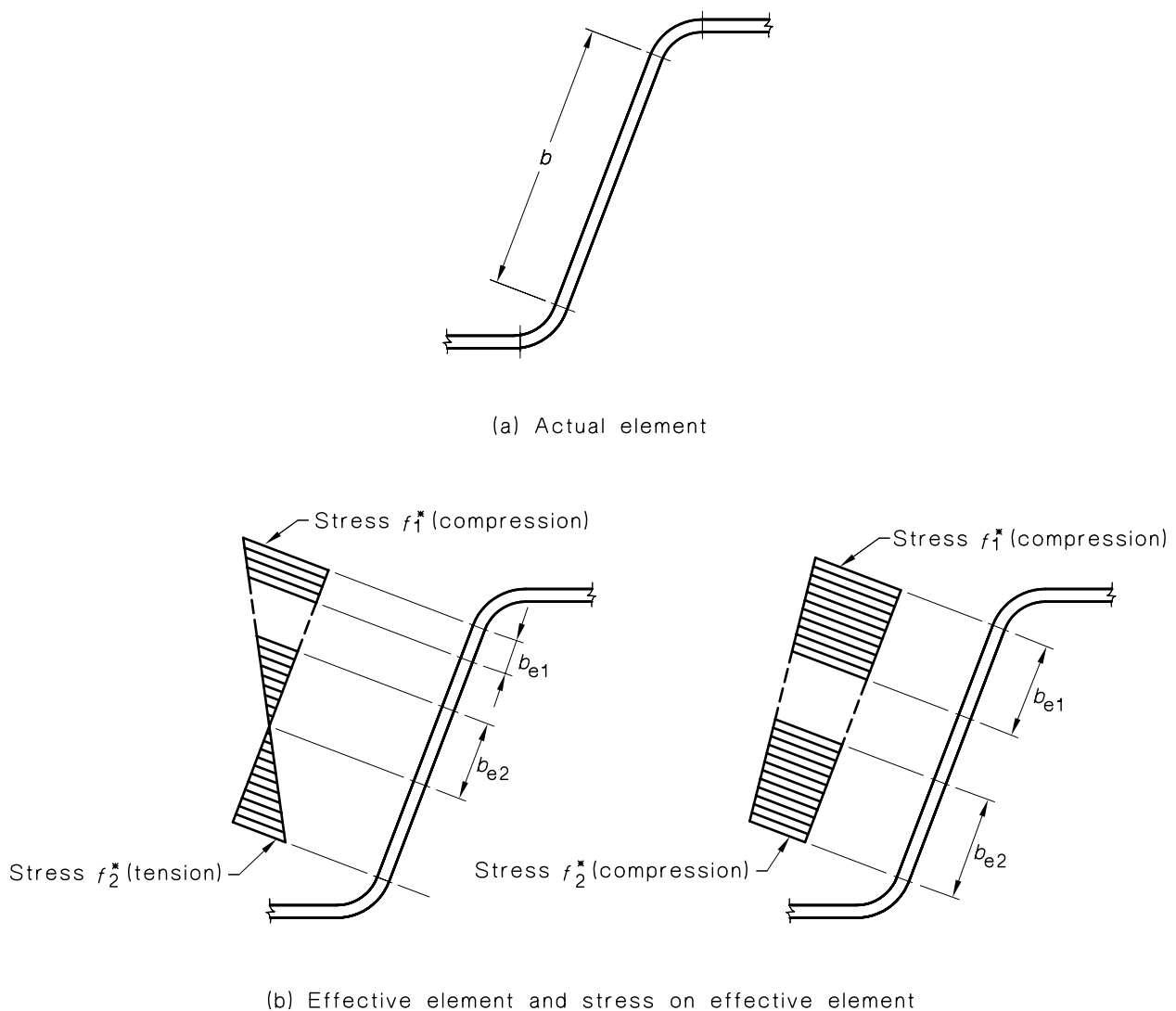


FIGURE 2.2.2 STIFFENED ELEMENTS WITH STRESS GRADIENT AND WEBS

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 0.5 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 Clause 2.2.1.3 except that f_d^* shall be substituted for f^* and k is equal to 0.5.

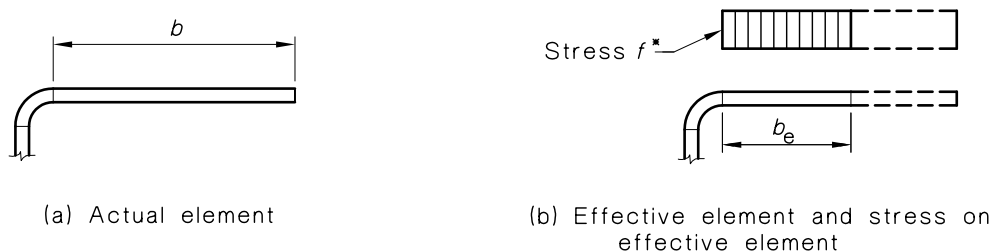


FIGURE 2.3.1 UNSTIFFENED ELEMENT WITH UNIFORM COMPRESSION

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) of unstiffened compression elements and edge stiffeners with stress gradient shall be determined in accordance with Clause 2.2.1.2 with f^* equal to f_3^* as shown in Figures 2.3.2 and 2.4.2, and k equal to 0.5. Values of the plate buckling coefficient (k) given in Appendix I may be used in lieu of 0.5.

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.

2.3.2.3 Effective width for deflection calculations

For determining the deflection, the effective widths (b_{ed}) of unstiffened compression elements and edge stiffeners with stress gradient shall be determined in accordance with Clause 2.2.1.3 except that f_{d3}^* shall be substituted for f^* and k is equal to 0.5. Values of the plate buckling coefficient (k) given in Appendix I may be used in lieu of 0.5.

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.

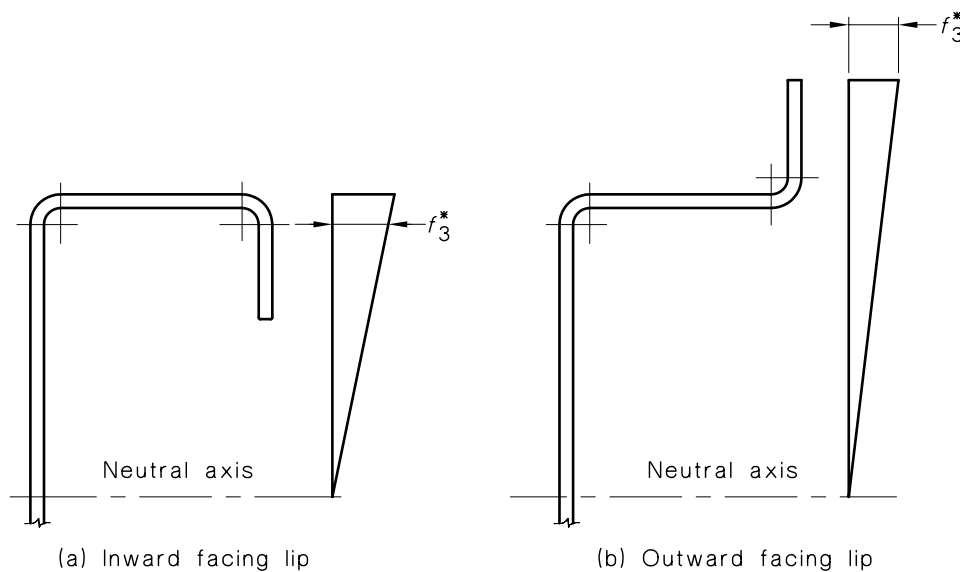


FIGURE 2.3.2 UNSTIFFENED COMPRESSION ELEMENTS SUBJECT TO A STRESS GRADIENT

2.4 EFFECTIVE WIDTHS OF UNIFORMLY COMPRESSED ELEMENTS WITH AN EDGE STIFFENER OR ONE INTERMEDIATE STIFFENER

2.4.1 Notation

For the purpose of this Clause—

A_s = reduced area of the stiffener. A_s shall be used in calculating the overall effective section properties. The centroid of the stiffener shall be considered located at the centroid of the full area of the stiffener, and the second moment of area of the stiffener about its own centroidal axis shall be that of the full section of the stiffener

A_{se} = effective area of the stiffener
 $= d_{se}t$ (for stiffener shown in Figure 2.4.2) . . . 2.4.1(1)

b = flat width of element excluding radii (see Figures 2.4.1(a) and 2.4.2(a))

b_2 = flat width of element with intermediate stiffener excluding radii (see Figure 2.4.1(a))

C_1, C_2 = coefficients (see Figure 2.4.2(b))

d, d_1 = actual stiffener dimension (see Figure 2.4.2(a))

d_s = reduced effective width of the stiffener (see Figure 2.4.2(a)). The value of d_s calculated in accordance with Clause 2.4.3, shall be used in calculating the overall effective section properties

d_{se} = effective width of the stiffener calculated in accordance with Clause 2.3.1 (see Figure 2.4.2(a))

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

I_s = second moment of area of the full stiffener about its own centroidal axis parallel to the element to be stiffened

$$= \frac{d^3 t \sin^2 \theta}{12} \quad (\text{for stiffener shown in Figure 2.4.2}) \quad \dots 2.4.1(2)$$

k = plate buckling coefficient

S = slenderness factor

$$= 1.28 \sqrt{\frac{E_o}{f^*}} \quad \dots 2.4.1(3)$$

For edge stiffeners, the round corner between the stiffener and the element to be stiffened shall not be considered as part of the stiffener.

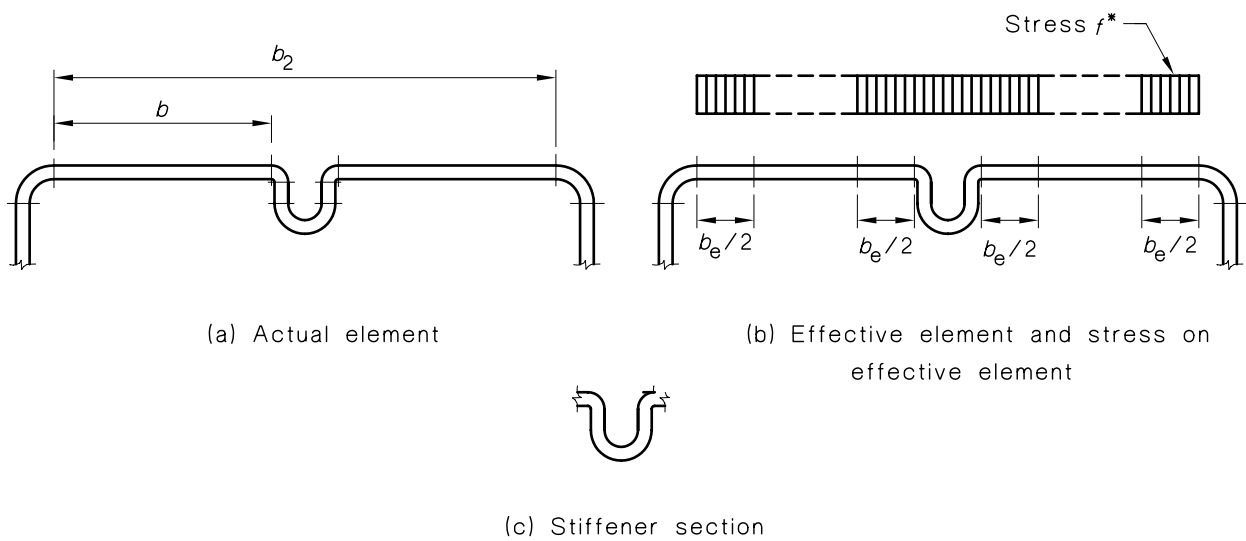
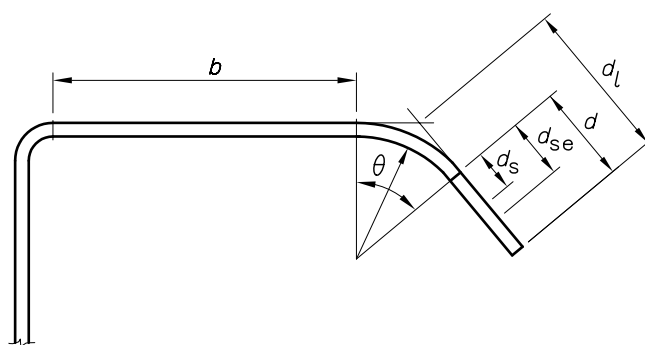
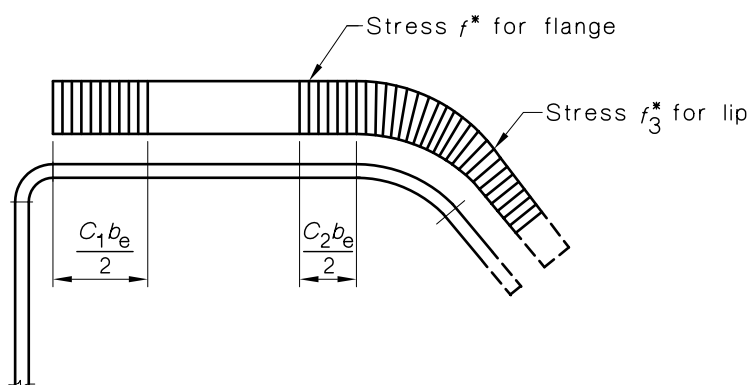


FIGURE 2.4.1 ELEMENTS WITH INTERMEDIATE STIFFENER



(a) Actual and effective stiffener



(b) Effective element and stress on effective element

FIGURE 2.4.2 ELEMENTS WITH EDGE STIFFENER

2.4.2 Elements with an intermediate stiffener

2.4.2.1 General

For uniformly compressed elements with an intermediate stiffener, the effective widths for section or member capacity and deflection calculations shall be determined in accordance with Clauses 2.4.2.2 and 2.4.2.3, respectively.

2.4.2.2 Effective width for capacity calculations

For determining the section or member capacity, the effective widths (b_e) of uniformly compressed elements with an intermediate stiffener shall be determined for the following cases:

(a) Case I: $\frac{b_2}{t} \leq S$

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

$b_e = b$

.. 2.4.2.2(1)

$A_s = A_{se}$

.. 2.4.2.2(2)

- (b) Case II: $S < \frac{b_2}{t} < 3S$

$$\frac{I_a}{t^4} = \frac{50 \left(\frac{b_2}{t} \right)}{S} - 50 \quad \dots 2.4.2.2(3)$$

b_e shall be calculated in accordance with Clause 2.2.1.2

where

$$k = 3 \left(\sqrt{\frac{I_s}{I_a}} \right) + 1 \leq 4 \quad \dots 2.4.2.2(4)$$

$$A_s = A_{se} \left(\frac{I_s}{I_a} \right) \leq A_{se} \quad \dots 2.4.2.2(5)$$

A_{se} shall be calculated in accordance with Clause 2.2.1.2.

- (c) Case III: $\frac{b_2}{t} \geq 3S$

$$\frac{I_a}{t^4} = \left[\frac{128 \left(\frac{b_2}{t} \right)}{S} \right] - 285 \quad \dots 2.4.2.2(6)$$

b_e shall be calculated in accordance with Clause 2.2.1.2

where

$$k = 3 \left(\frac{I_s}{I_a} \right)^{1/3} + 1 \leq 4 \quad \dots 2.4.2.2(7)$$

$$A_s = A_{se} \left(\frac{I_s}{I_a} \right) \leq A_{se} \quad \dots 2.4.2.2(8)$$

A_{se} shall be calculated in accordance with Clause 2.2.1.2.

2.4.2.3 Effective width for deflection calculations

For determining the deflection, the effective widths (b_e) shall be determined in accordance with Clause 2.4.2.2, except that f_d^* shall be substituted for f^* .

2.4.3 Elements with an edge stiffener

2.4.3.1 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 2.4.3.2 and 2.4.3.3, respectively.

2.4.3.2 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 for the following cases:

(a) Case I: $\frac{b}{t} \leq \frac{S}{3}$

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

$b_e = b$. . . 2.4.3.2(1)

$d_s = d_{se}$ (for simple lip stiffener) . . . 2.4.3.2(2)

$A_s = A_{se}$ (for other stiffener shapes) . . . 2.4.3.2(3)

(b) Case II: $\frac{S}{3} < \frac{b}{t} < S$

$$\frac{I_a}{t^4} = 399 \left[\frac{(b/t)}{S} - \sqrt{\frac{k_u}{4}} \right]^3 \quad \dots 2.4.3.2(4)$$

$n = 0.5$

$$C_2 = \frac{I_s}{I_a} \leq 1 \quad \dots 2.4.3.2(5)$$

$$C_1 = 2 - C_2 \quad \dots 2.4.3.2(6)$$

b_e shall be calculated in accordance with Clause 2.2.1.2, where k shall be determined as follows:

$$k = C_2^n (k_a - k_u) + k_u \quad \dots 2.4.3.2(7)$$

$$k_u = 0.43$$

For simple lip stiffener with $140^\circ \geq \theta \geq 40^\circ$ and $d_l/b \leq 0.8$, where θ is as shown in Figure 2.4.2:

$$k_a = 5.25 - 5(d_l/b) \leq 4.0 \quad \dots 2.4.3.2(8)$$

$$d_s = C_2 d_s \quad \dots 2.4.3.2(9)$$

For stiffener shape other than simple lip:

$$k_a = 4.00$$

$$A_s = C_2 A_{se} \leq A_{se} \quad \dots 2.4.3.2(10)$$

(c) Case III: $\frac{b}{t} \geq S$

$$\frac{I_a}{t^4} = \left[\frac{115(b/t)}{S} \right] + 5 \quad \dots 2.4.3.2(11)$$

C_1 , C_2 , b_e , k , d_s , A_s shall be calculated in accordance with Case II with n equal to 0.333.

2.4.3.3 Effective width for deflection calculations

For determining the deflection, the effective widths (b_e) shall be determined in accordance with Clause 2.4.3.2, except that f_d^* shall be substituted for f^* .

2.5 EFFECTIVE WIDTHS OF EDGE-STIFFENED ELEMENTS WITH ONE OR MORE INTERMEDIATE STIFFENERS, OR STIFFENED ELEMENTS WITH MORE THAN ONE INTERMEDIATE STIFFENER

For determining the effective width (b_e), the intermediate stiffener of an edge-stiffened element or the stiffeners of a stiffened element with more than one stiffener shall be disregarded unless each intermediate stiffener has the following minimum I_s :

$$I_{s, \text{ min.}} = 3.66t^4 \left[\sqrt{\left(\frac{b}{t}\right)^2 - \left(\frac{0.119E_o}{f_y}\right)} \right] \geq 18.4t^4 \quad \dots 2.5(1)$$

where

I_s = second moment of area of the full stiffener about its own centroidal axis parallel to the element to be stiffened

$\frac{b}{t}$ = width-to-thickness ratio of the larger stiffened sub-element.

In addition, the following shall be considered:

- Where the spacing of intermediate stiffeners between two webs is such that for the sub-element between the stiffeners, b_e is less than b as determined in accordance with Clause 2.2.1.2, only two intermediate stiffeners, those nearest each web, shall be considered effective.
- Where the spacing of intermediate stiffeners between a web and an edge stiffener is such that for the sub-element between the stiffeners, b_e is less than b as determined in accordance with Clause 2.2.1.2, only one intermediate stiffener, that nearest the web, shall be considered effective.
- Where intermediate stiffeners are spaced so closely that for the elements between the stiffeners, b_e is equal to b as determined in accordance with Clause 2.2.1.2, all the stiffeners may be considered effective. In calculating the flat-width-to-thickness ratio of the entire multiple-stiffened element, such element shall be considered as replaced by an equivalent element without intermediate stiffeners whose width (b_2) shall be the full width between webs or from web to edge stiffener, and whose equivalent thickness of the stiffener (t_s) shall be determined from the following Equation:

$$t_s = \sqrt[3]{\frac{12I_{sf}}{b_2}} \quad \dots 2.5(2)$$

where I_{sf} is the second moment of area of the full area of the multiple-stiffened element, including the intermediate stiffeners, about its own centroidal axis. The second moment of area of the entire section shall be calculated assuming the equivalent element to be located at the centroidal axis of the multiple stiffened element, including the intermediate stiffener. The actual extreme fibre distance shall be used in calculating the section modulus.

- If b/t is greater than 60, the effective width (b_e) of the sub-element or element shall be determined from the following Equation:

$$\frac{b_{es}}{t} = \left(\frac{b_e}{t}\right) - 0.1\left(\frac{b}{t} - 60\right) \quad \dots 2.5(3)$$

where

b/t = flat-width ratio of the sub-element or element

b_{es} = effective width of the sub-element or element to be used in design calculations

b_e = effective width determined in accordance with Clause 2.2.1.2

To calculate the effective structural properties of a member having compression sub-elements or element subjected to the above reduction in effective width, the area of stiffeners (edge stiffener or intermediate stiffeners) shall be considered reduced to an effective area as follows:

$$(i) \quad \text{For } 60 < \frac{b}{t} < 90: \quad A_{\text{ef}} = \alpha A_s \quad \dots 2.5(4)$$

where

$$\alpha = \left(3 - \frac{2b_{\text{es}}}{b} \right) - \frac{1}{30} \left(1 - \frac{b_{\text{es}}}{b} \right) \left(\frac{b}{t} \right) \quad \dots 2.5(5)$$

$$(ii) \quad \text{For } \frac{b}{t} \geq 90: \quad A_{\text{ef}} = \left(\frac{b_{\text{es}}}{b} \right) A_s \quad \dots 2.5(6)$$

In Equations 2.5(4) and 2.5(6), A_{ef} and A_s apply only to the area of the stiffener section, exclusive of any portion of adjacent elements.

The centroid of the stiffener shall be considered at the centroid of the full area of the stiffener, and the second moment of area of the stiffener about its own centroidal axis shall be that of the full section of the stiffener.

2.6 STIFFENERS

2.6.1 Transverse stiffeners

Transverse stiffeners attached to beam webs at points of concentrated loads or reactions shall be designed as compression members. Concentrated loads or reactions shall be applied directly into the stiffeners, or each stiffener shall be fitted accurately to the flat portion of the flange to provide direct loadbearing into the end of the stiffener. Means for shear transfer between the stiffener and the web shall be provided in accordance with Section 3. The design concentrated loads or reactions (N^*) shall satisfy the following:

$$(a) \quad N^* \leq \phi_c N_s \quad \dots 2.6.1(1)$$

$$(b) \quad N^* \leq \phi_c N_c \quad \dots 2.6.1(2)$$

Where

$$\begin{aligned} \phi_c &= \text{capacity [strength reduction] factor for members in compression} \\ &= 0.85 \end{aligned}$$

$$\begin{aligned} N_s &= \text{nominal section capacity of a member in compression (see Clause 3.4)} \\ &= f_{\text{wy}} A_{s1} \end{aligned}$$

$$\begin{aligned} N_c &= \text{nominal member capacity of a member in compression (see Clause 3.4)} \\ &= f_n A_{s2} \end{aligned}$$

$$f_{\text{wy}} = \text{lower yield stress value of the beam web } (f_y) \text{ or of the stiffener section } (f_{ys})$$

$$f_n = \text{buckling stress (see Clause 3.4)}$$

$$A_{s1}, A_{s2} = \text{area of a member in compression consisting of the transverse stiffeners and a portion of the web}$$

$$\begin{aligned} A_{s1} &= 18t^2 + A_s \\ &\quad (\text{for transverse stiffeners at interior support and under concentrated load}) \quad \dots 2.6.1(3) \end{aligned}$$

$$\begin{aligned} &= 10t^2 + A_s \\ &\quad (\text{for transverse stiffeners at end support}) \quad \dots 2.6.1(4) \end{aligned}$$

$$A_{s2} = b_1 t + A_s \quad \text{(for transverse stiffeners at interior support under concentrated load)} \quad \dots 2.6.1(5)$$

$$= b_2 t + A_s \quad \text{(for transverse stiffeners at end support)} \quad \dots 2.6.1(6)$$

t = base thickness of beam web

A_s = cross-sectional area of transverse stiffeners

$$b_1 = 25t \left[0.0024 \left(\frac{l_{st}}{t} \right) + 0.72 \right] \leq 25t \quad \dots 2.6.1(7)$$

$$b_2 = 12t \left[0.0044 \left(\frac{l_{st}}{t} \right) + 0.83 \right] \leq 12t \quad \dots 2.6.1(8)$$

l_{st} = length of transverse stiffener

The b/t_s ratio for the stiffened and unstiffened elements of cold-formed steel transverse stiffeners shall not exceed $1.28 \sqrt{E_o / f_{ys}}$ and $0.37 \sqrt{E_o / f_{ys}}$, respectively, where f_{ys} is the yield stress and t_s is the thickness of the stiffener steel.

2.6.2 Shear stiffeners

Where shear stiffeners are required, the spacing shall be such that the design shear force shall not be greater than the design shear capacity ($\phi_v V_v$) specified in Clause 3.3.4, and the ratio a/d_1 shall not be greater than $[260/(d_1/t)]^2$ and 3.0.

The actual second moment of area ($I_{s,min.}$) of a pair of attached shear stiffeners, or of a single shear stiffener, with reference to an axis in the plane of the web, shall have a minimum value as follows:

$$I_{s,min.} = 5d_1 t^3 \left[\frac{d_1}{a} - 0.7 \left(\frac{a}{d_1} \right) \right] \geq \left(\frac{d_1}{50} \right)^4 \quad \dots 2.6.2(1)$$

The gross area of shear stiffeners (A_{st}) shall be not less than—

$$A_c = \left(\frac{1-k_s}{2} \right) \left\{ \frac{a}{d_1} - \frac{\left(\frac{a}{d_1} \right)^2}{\left(\frac{a}{d_1} \right) + \sqrt{1 + \left(\frac{a}{d_1} \right)^2}} \right\} \psi k_{st} d_1 t \quad \dots 2.6.2(2)$$

where

k_s = shear stiffener coefficient

$$= \frac{1.53 E_o k_v}{f_y \left(\frac{d_1}{t} \right)^2} \quad \text{if } k_s \leq 0.8 \quad \dots 2.6.2(3)$$

$$= \frac{0.00248}{\left(\frac{d_1}{t} \right)} \left(\sqrt{\frac{k_v E_o}{f_y}} \right) \quad \text{if } k_s > 0.8 \quad \dots 2.6.2(4)$$