AS/NZS 1664.2:1997

Australian/New Zealand Standard®

Aluminium structures

Part 2: Allowable stress design

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Aluminium structures

Part 2: Allowable stress design

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PREFACE

This Joint Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee BD/50, Aluminium Structures, to supersede, in part, AS 1664—1979, *Rules for the use of aluminium in structures (known as SAA Aluminium Structures Code).*

This Standard is technically equivalent to *The Aluminium Design Manual: Specifications and guidelines for aluminium structures. Part 1A: Specifications for Aluminium structures allowable stress design* issued by the U.S. Aluminium Association Inc.

The objective of this Standard is to provide designers of aluminium alloy load carrying members and elements with allowable stress design criteria for use in design applications.

Statements expressed in mandatory terms in notes to tables and figures are deemed to be requirements of this Standard.

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SECTION 1 GENERAL

1.1 SCOPE This Standard specifies requirements for the design of aluminium alloy load carrying members and elements. The allowable stress design (ASD) criteria are intended as an alternative to the limit state design (LSD) criteria (see AS 1664.1). One design specification (ASD or LSD) applies throughout the design of a single structure.

1.2 MATERIALS The principal materials to which these specifications apply are aluminium alloys that comply with AS 1734, AS 1865, AS 1866, AS 1867 and AS 2848.1. Those structural members frequently used are listed in Table 3.3(A).

1.3 SAFETY FACTORS

1.3.1 Building type structures Basic allowable tensile stresses for buildings, structural supports for highway signs, luminaires, traffic signals and similar structures shall be the lesser of the minimum yield strength divided by a factor of safety of 1.65, or the minimum ultimate tensile strength divided by a factor of safety of 1.95. Other allowable stresses for buildings and similar structures shall be based upon the factors of safety shown in Table 3.4(A).

1.3.2 Bridge type structures Basic allowable tensile stresses for bridge type structures shall be the lesser of the minimum yield strength divided by a factor of safety of 1.85, or the minimum ultimate tensile strength divided by a factor of safety of 2.2. Other allowable stresses for bridge and similar structures shall be based upon the factors of safety shown in Table 3.4(A).

1.3.3 Other type structures Where it is customary or standard practice to use factors of safety other than those given in Clauses 1.3.1 or 1.3.2, the general formulas in Table 3.4(C) shall be permitted to be used with the desired factors of safety substituted for n_u, n_y or n_a.

1.4 REFERENCED DOCUMENTS The following documents are referred to in this Standard:

AS

1170	Minimum design loads on structures (known as the SAA Loading Code)
1170.1	Part 1: Dead and live loads and load combinations
1170.2	Part 2: Wind loads
1170.3	Part 3: Snow loads
1170.4	Part 4: Earthquake loads
1391	Methods for tensile testing of metals

AS/NZS

1664	Aluminium structures
1664.1	Part 1: Limit state design
1664.2	Supplement 1, Part 2: Allowable stress design—Commentary

AS	
1665	Welding of aluminium structures
1734	Aluminium and aluminium alloys—Flat sheet, coiled sheet and plate (adopted in New Zealand as NZS/AS 1734)
1865	Aluminium and aluminium alloys—Drawn wire, rod, bar and strip (adopted in New Zealand as NZS/AS 1865)
1866	Aluminium and aluminium alloys—Extruded rod, bar, solid and hollow shapes (adopted in New Zealand as NZS/AS 1866)
1867	Aluminium and aluminium alloys—Drawn tubes (adopted in New Zealand as NZS/AS 1867)
2848	Aluminium and aluminium alloys—Compositions and designations
2848.1	Part 1: Wrought products
NZS	
4203	Code of practice for general structural design and design loadings for buildings (1984 edition)
ASTM	
B 557	Test methods of tension testing wrought and cast aluminium- and magnesium-alloy products
D 962	Specification for aluminium powder and paste pigments for paints
E 330	Test method for structural performance of exterior windows, curtain walls, and doors by uniform static air pressure difference

SECTION 2 DESIGN PROCEDURE

2.1 PROPERTIES OF SECTIONS Properties of sections, such as cross-sectional area, moment of inertia, section modulus, radius of gyration and torsion constants, shall be determined in accordance with accepted methods of structural analysis.

2.2 PROCEDURE Computations of forces, moments, stresses and deflections shall be in accordance with accepted methods of elastic structural analysis and engineering design. The formulas and methods for determining allowable stresses in this Standard have been simplified in many cases for ease of computation but are not intended to preclude the use of more rigorous analysis.

2.3 LOADING The loads on the structure shall be in accordance with the applicable parts of AS 1170 (Australia) or the applicable parts of NZS 4203:1984 (New Zealand).

When computing allowable stresses in Australia, the most adverse load combination from the following shall be used:

(a) $G + Q$

(b) $0.75\ (G + Q + W_{\mathrm{p}})$

(c) $0.75\ (G + Q + F_{\mathrm{eq}})$

(d) $0.75\ (G' + W'_{\mathrm{p}})$

where

G = dead load

Q = live load

W_{p} = wind load based on basic wind speed V_{p}

F_{eq} = earthquake load

W'_{p} = wind load causing stresses of opposite sign to the dead load

G' = that part of the dead load that cannot be removed from the structure

In the case of wind and ice loads, the form of the structure and any of its exposed components (e.g. increased area exposed to wind due to icing) shall be considered.

SECTION 3 GENERAL DESIGN RULES

3.1 INTRODUCTION The nomenclature of terms used in developing the allowable stresses is given in Clause 3.2. Minimum mechanical properties for each alloy (non-welded material) included in this Standard are listed in Table 3.3(A).

Minimum mechanical properties for welded material are shown in Table 3.3(B).

3.2 NOMENCLATURE A consistent set of units shall be used throughout these specifications, as follows:

a = detail dimension parallel to the direction of stress

a_e = equivalent width of rectangular panel

a_1 = shorter dimension of rectangular panel

a_2 = longer dimension of rectangular panel

A = area

A, B, C, D, E, F = detail categories for fatigue

A_c = area of compression element (compression flange plus 1/3 of area of web between compression flange and neutral axis)

A_h = gross area of cross-section of horizontal stiffener

A_s = area of the stiffener

A_w = the portion of area of cross-section A lying within 25 mm of a weld

b = width of section or element

b_o = width of element with an intermediate stiffener as shown in Figure 3.4.10.3

b_e = effective width of flat plate element to be used in deflection calculations

b/t = width to thickness ratio of a rectangular element of a cross-section

B, D, C = buckling formula constants, with the following subscripts:

$_c$—compression in columns

$_p$—compression in flat plates

$_t$—compression in round tubes

$_{tb}$—bending in round tubes

$_{br}$—bending in rectangular bars

$_s$—shear in flat plates

c = distance from neutral axis to extreme fibre

C = coefficient which depends on screw location

C_b = coefficient which depends on moment gradient

C_m = $0.6 - 0.4(M_1/M_2)$ for members whose ends are prevented from swaying; or

0.85 for members whose ends are not prevented from swaying

C_p = correction factor

C_w = torsional warping constant of the cross-section

C_{wa} = $t^2 \sin\theta(0.46F_{cy} + 0.02\sqrt{EF_{cy}})$

C_{wb} = $C_3 + R_i(1 - \cos\theta)$

C_1 = 140 m; or
= coefficient defined in Clause 4.9.5

C_2 = 33 mm; or
= coefficient defined in Clause 4.9.2

C_3 = 10 mm

d = depth of section or beam

d_1 = clear distance from the neutral axis to the compression flange

d_s = length of lip stiffener shown in Figure 3.4.10.2(A)

D = diameter

D_h = nominal hole diameter

D_n = nominal dead load

D_s = defined in Figure 3.4.10.2(A)

D_w = nominal washer diameter

D_{ws} = larger of the nominal washer diameter and the screw head

e = base for natural logarithms $\simeq$ 2.72

E = compressive modulus of elasticity (See Table 3.3(A))

f = calculated stress

f_a = average stress on cross-section produced by axial load

f_b = maximum bending stress produced by transverse loads or bending moments, or both

f_s = shear stress caused by torsion or transverse shear loads

F = allowable stress

F_a = allowable compressive stress for a member considered as an axially loaded column according to Clauses 3.4.8 to 3.4.11

F_{ao} = allowable compressive stress of axially loaded member considered as a short column according to Clause 4.7.2

F_b = allowable bending stress for members subjected to bending only

F_{bu} = bearing ultimate strength

F_{buw} = bearing ultimate strength within 25 mm of a weld

F_{bu1} = bearing ultimate strength of member in contact with the screw head

F_{bu2} = bearing ultimate strength of member not in contact with the screw head

F_{by} = bearing yield strength

F_{byw} = bearing yield strength within 25 mm of a weld

F_{by1} = bearing yield strength of member in contact with the screw head

F_{by2} = bearing yield strength of member not in contact with the screw head

F_c = allowable compressive stress

F_{cr} = local buckling stress for element from Clause 4.7.1

F_{cy} = compressive yield strength

F_{cyw} = compressive yield strength across a butt weld (0.2 percent offset in 250 mm gauge length)

F_e = elastic buckling stress divided by n_u

$$= \frac{\pi^2 E}{n_u (kL/r)^2}$$

F_{ec} = allowable elastic lateral buckling stress of beam calculated assuming that the elements are not buckled

$$F_{ex} = \frac{\pi^2 E}{\left(\frac{k_x L_b}{r_x}\right)^2}$$

F_m = mean value of the fabrication factor

F_n = allowable stress for cross-section 25 mm or more from weld

F_{pw} = allowable stress for cross-section, part of whose area lies within 25 mm of a weld

F_{rb} = allowable stress for beam with buckled elements

F_{rc} = allowable stress for column with buckled elements

F_s = allowable shear stress for members subjected only to torsion or shear

F_{ST} = allowable stress according to Clause 3.4.10.2 or Clause 3.4.19

F_{su} = shear ultimate strength

F_{suw} = shear ultimate strength within 25 mm of a weld

F_{sy} = shear yield strength

F_{syw} = shear yield strength within 25 mm of a weld

F_t = allowable tensile stress for the member considered loaded only axially according to Clause 3.4.2

$$F_{tb} = \frac{1}{Ar_o^2}\left(GJ + \frac{\pi^2 E C_w}{(k_o L_t)^2}\right)$$

F_{tu} = tensile ultimate strength

F_{tuw} = tensile ultimate strength across a butt weld

F_{ty} = tensile yield strength

F_{tyw} = tensile yield strength across a butt weld (0.2 percent offset in 250 mm gauge length)

F_{tu1} = tensile ultimate strength of member in contact with the screw head

F_{tu2} = tensile ultimate strength of member not in contact with the screw head

F_{UT} = allowable stress according to Clause 3.4.10.2 or Clause 3.4.19

F_y = either F_{ty} or F_{cy}, whichever is smaller

F_w = allowable stress on cross-section if entire area were to lie within 25 mm of weld

g = distance from shear centre to the point of application of load

g_r	=	spacing of rivet or bolt holes perpendicular to direction of load
G	=	shear modulus
G_r	=	grip of rivet or bolt
h	=	clear height of shear web
I	=	moment of inertia
I_b	=	required moment of inertia of bearing stiffener
I_{cy}	=	moment of inertia of compression flange about web
I_h	=	moment of inertia of horizontal stiffener
I_o	=	moment of inertia of the stiffener about the centroidal axis of the stiffener parallel to the flat plate element that is stiffened
I_s	=	moment of inertia of transverse stiffener to resist shear buckling
I_x	=	moment of inertia of a beam about axis perpendicular to web
I_y	=	moment of inertia of a beam about axis parallel to web
I_{yc}	=	moment of inertia of compression element about axis parallel to vertical web
j	=	parameter defined by Equation 4.9.4(3) or (4)
J	=	torsion constant
k	=	the effective length factor. k is taken as larger than or equal to unity unless rational analysis justifies a smaller value
k_c	=	coefficient for compression members
k_o	=	effective length coefficient for torsional buckling. k_o is taken as larger than or equal to unity unless rational analysis justifies a smaller value
k_t	=	coefficient for tension members
k_x	=	effective length coefficient for buckling about the x-axis
k_y	=	effective length coefficient for buckling about the y-axis
k_1	=	coefficient for determining slenderness limit S_2 for sections for which the allowable compressive stress is based on ultimate strength
k_2	=	coefficient for determining allowable compressive stress in sections with slenderness ratio above S_2 for which the allowable compressive stress is based on ultimate strength
K	=	constant to be determined from Table 4.8.2
L	=	unsupported length in the plane of bending
L_b	=	unbraced length for bending
L_n	=	nominal live load
L_o	=	length of tube between circumferential stiffeners
L_t	=	unbraced length for twisting
m	=	constant determined from Table 4.8.2
M	=	bending moment applied to the member

M_a = allowable bending moment for the member if bending moment alone is applied to the member

M_A = absolute value of moment at quarter-point of the unbraced beam segment

M_B = absolute value of moment at mid-point of the unbraced beam segment

M_C = absolute value of moment at three-quarter-point of the unbraced beam segment

M_e = elastic critical moment

M_i = bending strength of member with intermediate thickness

M_m = mean value of the material factor

M_{MAX} = absolute value of maximum moment in the unbraced beam segment

M_1 = bending strength of member of thinnest material

M_2 = bending strength of member of thickest material

M_1/M_2 = ratio of end moments where M_2 is the larger of the two end moments and M_1/M_2 is positive when the member is bent in reverse curvature, negative when bent in single curvature

n = number of tests

n_a = factor of safety on appearance of buckling

n_s = factor of safety for screw connections

n_u = factor of safety on ultimate strength

n_y = factor of safety on yield strength

N = number of cycles to failure

N_b = length of bearing at reaction or concentrated load

N_s = number stress ranges in the spectrum

P = concentrated load on bearing stiffener

P_{as} = allowable shear force per screw

P_{at} = allowable tensile force per screw

P_c = allowable reaction or concentrated load per web

P_{not} = pull-out force per screw

P_{nov} = pull-over force per screw

P_{ns} = nominal shear strength per screw

P_{nt} = nominal tensile strength per screw

P_w = applied interior reaction or concentrated load per web for flat webs

q = uniform design load

r = radius of gyration

r_o = $\sqrt{r_{x^2} + r_{y^2} + x_{o^2} + y_{o^2}}$

r_s = radius of gyration of the stiffener

r_x, r_y = radii of gyration of the cross-section about the centroidal principal axes

r_y = radius of gyration of a beam (about axis parallel to web). (For beams that are unsymmetrical about the horizontal axis, r_y shall be calculated as though both flanges were the same as the compression flange)

r_{ye} = effective radius of gyration

R = ratio defined in Clauses 3.4.10.2 and 3.4.19

R_b = mid-thickness radius of curvature of curved plate and tubular beam elements

R_i = bend radius at juncture of flange and web measured to inside surface of bend

R_m = mid-thickness radius of round tubular column or maximum mid-thickness radius of oval tubular column

R_o = outside radius of round tube or maximum outside radius of oval tube

R_p = average value of failure loads in all tests

R_t = transition radius, the radius of an attachment of the weld detail

s = spacing of transverse stiffeners (clear distance between stiffeners for stiffeners consisting of a pair of members, one on each side of the web, centre-to-centre distance between stiffeners consisting of a member on one side of the web only); spacing of rivet or bolt holes parallel to direction of load

S = $1.28\sqrt{\dfrac{E}{F_{cy}}}$

SR = stress ratio, the ratio of minimum stress to maximum stress

S_{ra} = the applied stress range

S_{rd} = allowable stress range

S_{re} = equivalent stress range

S_{ri} = the ith stress range in the spectrum

S_x = standard deviation of the test results

S_1, S_2 = slenderness limits

t = thickness of flange, plate, web or tube (for tapered flanges, t is the average thickness)

t_i = thickness of the intermediate thickness material tested

t_1 = thickness of member in contact with the screw head

t_2 = thickness of member not in contact with the screw head

U = parameter defined by Equation 4.9.4(5)

V = shear force on web at stiffener location

V_F = coefficient of variation of the fabrication factor

V_M = coefficient of variation of the material factor

V_P = coefficient of variation of the ratio of the observed failure loads divided by the average value of all the observed failure loads

V_Q = coefficient of variation of the loads

X_o = x-coordinate of the shear centre

X_a	=	strength at which 99 percent of the material is expected to conform at a confidence level of 95 percent
X_m	=	mean of the test results
y_o	=	y-coordinate of the shear centre
Z_c	=	section modulus of a beam, compression side
Z_t	=	section modulus of a beam, tension side
α	=	a factor equal to unity for a stiffener consisting of equal members on both sides of the web and equal to 3.5 for a stiffener consisting of a member on one side only
α_1	=	number of cycles in the spectrum of the ith stress range divided by the total number of cycles
β	=	$1-(x_o/r_o)^2$
β_o	=	the target reliability index
β_s	=	spring constant (transverse force applied to the compression flange of the member of unit length divided by the deflection due to the force)
λ_s	=	equivalent slenderness ratio for an intermediate stiffener
θ	=	angle between plane of web and plane of bearing surface ($\theta \leq 90$ degrees)

3.3 TABLES RELATING TO MECHANICAL PROPERTIES AND BUCKLING CONSTANTS Formulas for determining allowable stresses and constants and coefficients needed for these formulas are given in Tables 3.3(A), 3.3(B), 3.3(C) and 3.3(D).

TABLE 3.3(A)

MINIMUM MECHANICAL PROPERTIES FOR ALUMINIUM ALLOYS

Alloy and temper	Product	Thickness range	Tension		Compression	Shear		Bearing		Compressive modulus of elasticity†
			F_{tu}*	F_{ty}*	F_{cy}	F_{su}	F_{sy}	F_{bu}	F_{by}	E
		mm	MPa	MPa	MPa	MPa	MPa	MPa	MPa	MPa
1100-H12	Sheet, plate	All	96	76	69	63	45	193	124	70 000
-H14	Rolled rod & bar	All	110	96	90	69	55	220	145	70 000
1200-H12	Sheet, plate, drawn tube	≤50	96	75	69	62	45	193	124	69 637
-H14	Sheet, plate, drawn tube	≤25	110	96	90	69	55	221	145	69 637
2014-T6	Sheet	1.0–6.5	455	400	407	276	227	860	640	75 000
-T651	Plate	6.4–50	462	407	400	276	234	875	648	75 000
-T6, T6510, T6511	Extrusions	All	414	365	359	241	213	786	586	75 000
-T6, T651	Cold finished rod & bar, drawn tube	All	448	379	365	262	220	855	606	75 000
Alclad										
2014-T6	Sheet	0.6–1.0	434	379	386	262	220	827	606	74 000
-T6	Sheet	1.0–6.3	441	393	400	269	227	841	627	74 000
-T651	Plate	6.3–12.7	441	393	386	269	227	841	627	74 000
3003-H12	Sheet & plate	0.4–50	117	83	69	76	48	234	131	70 000
-H14	Sheet & plate	0.2–25	138	117	96	83	69	276	172	70 000
-H16	Sheet	0.15–4	165	145	124	96	83	317	214	70 000
-H18	Sheet	0.15–3.2	186	165	138	103	96	338	234	70 000
3003-H12	Drawn tube	All	117	83	76	76	48	234	131	70 000
-H14	Drawn tube	All	138	117	110	83	69	276	172	70 000
-H16	Drawn tube	All	165	145	131	96	83	317	214	70 000
-H18	Drawn tube	All	186	165	145	103	96	338	234	70 000
Alclad										
3003-H12	Sheet & plate	0.4–50	110	76	62	69	45	220	124	70 000
-H14	Sheet & plate	0.2–25	131	110	90	82	62	262	165	70 000
-H16	Sheet	0.15–4	158	138	117	96	83	303	207	70 000
-H18	Sheet	0.15–3.2	179	158	131	103	90	324	220	70 000
Alclad										
3003-H14	Drawn tube	0.6–6.6	131	110	103	82	62	262	165	70 000
-H18	Drawn tube	0.2–12.7	179	158	138	103	90	324	220	70 000
3004-H32	Sheet & plate	0.4–50	193	145	124	117	83	386	248	70 000
-H34	Sheet & plate	0.2–25	220	172	152	131	96	441	276	70 000
-H36	Sheet	0.15–1.6	241	193	172	138	110	482	310	70 000
-H38	Sheet	0.15–3.2	262	214	200	145	124	496	310	70 000
3004-H34	Drawn tube	0.5–11.4	220	172	165	131	96	441	276	70 000
-H36	Drawn tube	0.5–11.4	241	193	186	138	110	482	310	70 000
Alclad										
3004-H32	Sheet	0.4–6.3	186	138	117	110	83	372	234	70 000
-H34	Sheet	0.2–6.3	214	165	145	124	96	427	262	70 000
-H36	Sheet	0.15–1.6	234	186	165	131	110	469	296	70 000
-H38	Sheet	0.15–3.2	255	207	193	145	117	483	303	70 000
-H14	Sheet & plate	0.2–12	220	179	165	131	103	441	269	70 000
-H16	Sheet	0.15–4.1	241	207	193	138	117	455	310	70 000
-H131, H241, H341	Sheet	0.6–1.3	214	179	152	124	103	427	269	70 000
-H151, H261, H361	Sheet	0.6–1.3	234	207	193	131	117	455	310	70 000
3005-H25	Sheet	0.3–1.3	179	151	138	103	89	338	241	70 000
-H28	Sheet	0.15–2.0	214	186	172	117	110	386	262	70 000
3006-H391	Sheet	0.25–1.3	214	186	186	138	110	414	303	70 000
3105-H25	Sheet	0.3–2.0	158	131	117	96	76	303	193	70 000
3203-H14	Sheet, plate	≤12	139	117	97	83	69	276	172	69 637
-H16	Sheet	≤4	162	138	117	97	83	303	206	69 637

(continued)

TABLE 3.3(A) *(continued)*

Alloy and temper	Product	Thickness range	Tension		Compression F_{cy}	Shear		Bearing		Compressive modulus of elasticity† E
			F_{tu}*	F_{ty}*		F_{su}	F_{sy}	F_{bu}	F_{by}	
		mm	MPa	MPa	MPa	MPa	MPa	MPa	MPa	MPa
5005-H12	Sheet & plate	0.4–50	124	96	90	76	55	234	152	70 000
-H14	Sheet & plate	0.2–25	145	117	103	83	69	276	172	70 000
-H16	Sheet	0.15–1.6	165	138	124	96	83	331	207	70 000
-H32	Sheet & plate	0.4–50	117	83	76	76	48	234	138	70 000
-H34	Sheet & plate	0.2–25	138	103	96	83	58	276	165	70 000
-H36	Sheet	0.15–1.6	158	124	110	90	76	331	200	70 000
5050-H32	Sheet	0.4–6.3	152	110	96	96	62	303	186	70 000
-H34	Sheet	0.2–6.3	172	138	124	103	83	345	220	70 000
-H32	Cold fin. rod & bar* Drawn tube	All	152	110	103	90	62	303	186	70 000
-H34	Cold fin. rod & bar* Drawn tube	All	172	138	131	103	83	345	220	70 000
5052-H32	Sheet & plate	All	214	158	145	131	90	414	269	70 000
-H34	Cold fin. rod & bar Drawn tube	All	234	179	165	138	103	448	303	70 000
-H36	Sheet	0.15–4.1	255	200	179	152	117	483	317	70 000
-H38	Sheet	≤3.25	268	220	207	152	124	510	338	70 327
-H391	Sheet	≤2	290	241	227	159	138	524	358	70 327
5083-H111	Extrusions	Up to 12	276	165	145	165	96	538	282	72 000
-H111	Extrusions	Over 12	276	165	145	158	96	538	262	72 000
-H321, H116	Sheet & plate	4.8–38	303	214	179	179	124	579	365	72 000
-H321, H116	Plate	38–76	283	200	165	165	117	538	338	72 000
-H323	Sheet	0.4–6.3	310	234	220	179	138	607	400	72 000
-H343	Sheet	0.4–6.3	345	269	255	200	158	655	455	72 000
5086-H111	Extrusions	Up to 12	248	145	124	145	83	483	248	72 000
-H111	Extrusions	Over 12	248	145	124	145	83	483	234	72 000
-H112	Plate	6–12	248	124	117	152	69	496	214	72 000
-H112	Plate	12–25	241	110	110	145	62	483	193	72 000
-H112	Plate	25–50	241	96	103	145	55	483	193	72 000
-H112	Plate	50–70	234	96	103	145	55	469	193	72 000
-H116, H32	Sheet & plate	All	276	193	179	165	110	538	331	72 000
-H34	Drawn tube	All	303	234	220	179	138	579	400	72 000
5154-H38	Sheet	0.15–3.2	310	241	227	165	138	558	386	72 000
5251-H34	Sheet, plate	≤25	231	179	159	131	103	434	303	70 327
5454-H111	Extrusions	Up to 12	228	131	110	138	76	441	220	72 000
-H111	Extrusions	Over 12	228	131	110	131	76	441	207	72 000
-H112	Extrusions	Up to 127	214	83	90	131	48	427	165	72 000
-H32	Sheet & plate	0.5–50	248	179	165	145	103	483	303	72 000
-H34	Sheet & plate	0.5–25	269	200	186	158	117	510	338	72 000
5456-H111	Extrusions	Up to 12	290	179	152	172	103	565	303	72 000
-H111	Extrusions	Over 12	290	179	152	165	103	565	290	72 000
-H112	Extrusions	Up to 127	283	131	138	165	76	565	262	72 000
-H116, H321	Sheet & plate	4.8–32	317	227	186	186	131	600	386	72 000
-H116, H321	Plate	32–38	303	214	172	172	124	579	365	72 000
-H116, H321	Plate	38–76	283	200	172	172	117	565	338	72 000
6005-T5	Extrusions	Up to 25	262	241	241	165	138	552	386	70 000
6105-T5	Extrusions	Up to 25	262	241	241	165	138	552	386	70 000
6061-T6, T651	Sheet & plate	0.25–102	290	241	241	186	138	607	400	70 000
-T6, T6510, T6511	Extrusions	Up to 25	262	241	241	165	138	551	386	70 000
-T6, T651	Cold fin. rod & bar	Up to 200	290	241	241	172	138	607	386	70 000
-T6	Drawn tube	0.6–12	290	241	241	186	138	607	386	70 000
-T6	Pipe	Up to 25	290	241	241	186	138	607	386	70 000
-T6	Pipe	Over 25	262	241	241	165	138	551	386	70 000

(continued)

TABLE 3.3(A) (*continued*)

Alloy and temper	Product	Thickness range	Tension		Compression F_{cy}	Shear		Bearing		Compressive modulus of elasticity† E
			F_{tu}*	F_{ty}*		F_{su}	F_{sy}	F_{bu}	F_{by}	
		mm	MPa	MPa	MPa	MPa	MPa	MPa	MPa	MPa
6063-T5	Extrusions	Up to 12	152	110	110	90	62	317	179	70 000
-T5	Extrusions	Over 12	145	103	103	83	59	303	165	70 000
-T6	Extrusions & pipe	All	207	172	172	131	96	434	276	70 000
-T83	Drawn tube	All	275	248	248	165	138	579	393	69 637
6351-T5	Extrusions	Up to 25	262	241	241	165	138	551	386	70 000
-T6	Extrusions	≤150	293	255	255	172	145	607	421	69 637

* F_{tu} and F_{ty} are minimum specified values (except F_{ty} for 1100-H12, -H14 cold finished rod and bar and drawn tube, Alclad 3003-H18 sheet and 5050-H32, -H34 cold finished rod and bar which are minimum expected values); other strength properties are corresponding minimum expected values.

† Typical values. For deflection calculations an average modulus of elasticity is used; numerically this is 700 MPa lower than values in this column.

TABLE 3.3(B)

MINIMUM MECHANICAL PROPERTIES FOR WELDED ALUMINIUM ALLOYS

Alloy and temper	Product and thickness range	Tension		Compression F_{cyw}†	Shear		Bearing	
		F_{tuw}*	F_{tyw}†		F_{suw}	F_{syw}	F_{buw}	F_{byw}
	mm	MPa	MPa	MPa	MPa	MPa	MPa	MPa
1100-H12, H14	All	76	31	31	55	17	158	55
3003-H12, H14, H16, H18	All	96	48	48	69	27	207	83
Alclad 3003-H12, H14, H16, H18	All	90	41	41	69	24	207	76
3004-H32, H34, H36, H38	All	152	76	76	96	45	317	138
Alclad 3004-H32, H34, H36, H38	All	145	76	76	90	45	303	131
3005-H25	Sheet	117	62	62	83	34	248	103
5005-H12, H14, H32, H34	All	96	48	48	62	27	193	69
5050-H32, H34	All	124	55	55	83	31	248	83
5052-H32, H34	All	172	90	90	110	52	345	131
5083-H111	Extrusions	269	145	138	158	83	538	221
-H116, H321	Sheet & plate 5–38	276	165	165	165	96	551	248
-H116, H321	Plate 38–76	269	158	158	165	90	538	234
-H323, H343	Sheet	276	165	165	165	96	551	248
5086-H111	Extrusions	241	124	117	145	69	483	193
-H112	Plate 6–12	241	117	117	145	65	483	193
-H112	Plate 12–25	241	110	110	145	62	483	193
-H112	Plate 25–51	241	96	96	145	55	483	193
-H32, H34, H116	Sheet & plate	241	131	131	145	76	483	193
5154-H38	Sheet	207	103	103	131	59	414	158
5454-H111	Extrusions	214	110	103	131	65	427	165
-H112	Extrusions	214	83	83	131	48	427	165
-H32, H34	Sheet & plate	214	110	110	131	65	427	165
5456-H111	Extrusions	283	165	152	165	96	565	262
-H112	Extrusions	283	131	131	165	76	565	262
-H116, H321	Sheet & plate 5–38	290	179	165	172	103	579	262
-H116, H321	Plate 38–76	283	165	158	172	96	565	262
6005-T5	Extrusions up to 6	165	117	117	103	69	345	207
6061-T6, T651, T6510, T6511‡	All	165	138	138	103	83	345	207
-T6, T651, T6510, T6511§	Over 9	165	103	103	103	62	345	207
6063-T5, T6	All	117	76	76	76	45	234	152
6351-T5‡	Extrusions	165	138	138	103	83	345	207
-T5§	Over 9	165	103	103	103	62	345	207

* Filler wires are recommended in Table 7.2(A), Values of F_{tuw} are ASME weld qualification values.

† 0.2 percent of offset in 250 mm gauge length across a butt weld.

‡ Values when welded with 5183, 5356 or 5556 alloy filler wire, regardless of thickness. Values also apply to thickness less than 10 mm, when welded with 4043, 5154, 5254, or 5554 alloy filler wire.

§ Values when welded with 4043, 5154, 5254, or 5554 alloy fire wire.

NOTE: When formulas from Table 3.4(C) in the specification section are applied to welded structures, the tensile ultimate strength F_{tu} shall be 90% of the F_{tuw} values given in the above table which are ASME weld qualification test values of ultimate strength.

TABLE 3.3(C)

FORMULAS FOR BUCKLING CONSTANTS FOR PRODUCTS WHOSE TEMPER DESIGNATION BEGINS WITH -O, -H, -T1, -T2, -T3, or -T4

Type of member and stress	Intercept, MPa	Slope, MPa	Intersection
Compression in columns and beam flanges	$B_c = F_{cy}\left[1 + \left(\frac{F_{cy}}{6900}\right)^{½}\right]$	$D_c = \frac{B_c}{20}\left(\frac{6B_c}{E}\right)^{½}$	$C_c = \frac{2B_c}{3D_c}$
Compression in flat plates	$B_p = F_{cy}\left[1 + \frac{(F_{cy})^{⅓}}{14.5}\right]$	$D_p = \frac{B_p}{20}\left(\frac{6B_p}{E}\right)^{½}$	$C_p = \frac{2B_p}{3D_p}$
Compression in round tubes under axial end load	$B_t = F_{cy}\left[1 + \frac{(F_{cy})^{1/5}}{8.5}\right]$	$D_t = \frac{B_t}{3.7}\left(\frac{B_t}{E}\right)^{⅓}$	C_t *
Compressive bending stress in solid rectangular bars	$B_{br} = 1.3F_{cy}\left[1 + \frac{(F_{cy})^{⅓}}{13.3}\right]$	$D_{br} = \frac{B_{br}}{20}\left(\frac{6B_{br}}{E}\right)^{½}$	$C_{br} = \frac{2B_{br}}{3D_{br}}$
Compressive bending stress in round tubes	$B_{tb} = 1.5F_y\left[1 + \frac{(F_y)^{1/5}}{8.5}\right]$	$D_{tb} = \frac{B_{tb}}{2.7}\left(\frac{B_{tb}}{E}\right)^{⅓}$	$C_{tb} = \left(\frac{B_{tb} - B_t}{D_{tb} - D_t}\right)^2$
Shear stress in flat plates	$B_s = F_{sy}\left[1 + \frac{(F_{sy})^{⅓}}{11.8}\right]$	$D_s = \frac{B_s}{20}\left(\frac{6B_s}{E}\right)^{½}$	$C_s = \frac{2B_s}{3D_s}$
Ultimate strength of flat plates in compression or bending	k_1 = 0.50, k_2 = 2.04		

* C_t can be found from a plot of curves of allowable stress based on elastic and inelastic buckling or by trial and error solution.

TABLE 3.3(D)

FORMULAS FOR BUCKLING CONSTANTS FOR PRODUCTS WHOSE TEMPER DESIGNATION BEGINS WITH -T5, -T6, -T7, -T8 or -T9

Type of member and stress	Intercept, MPa	Slope, MPa	Intersection
Compression in columns and beam flanges	$B_c = F_{cy}\left[1+\left(\frac{F_{cy}}{15510}\right)^{1/2}\right]$	$D_c = \frac{B_c}{10}\left(\frac{B_c}{E}\right)^{1/2}$	$C_c = 0.41\frac{B_c}{D_c}$
Compression in flat plates	$B_p = F_{cy}\left[1+\frac{(F_{cy})^{1/3}}{21.7}\right]$	$D_p = \frac{B_p}{10}\left(\frac{B_p}{E}\right)^{1/2}$	$C_p = 0.41\frac{B_p}{D_p}$
Compression in round tubes under axial end load	$B_t = F_{cy}\left[1+\frac{(F_{cy})^{1/5}}{12.8}\right]$	$D_t = \frac{B_t}{4.5}\left(\frac{B_t}{E}\right)^{1/3}$	C_t *
Compressive bending stress in solid rectangular bars	$B_{br} = 1.3F_{cy}\left[1+\frac{(F_{cy})^{1/3}}{13.3}\right]$	$D_{br} = \frac{B_{br}}{20}\left(\frac{6B_{br}}{E}\right)^{1/2}$	$C_{br} = \frac{2B_{br}}{3D_{br}}$
Compressive bending stress in round tubes	$B_{tb} = 1.5F_y\left[1+\frac{(F_y)^{1/5}}{12.8}\right]$	$D_{tb} = \frac{B_{tb}}{2.7}\left(\frac{B_{tb}}{E}\right)^{1/3}$	$C_{tb} = \left(\frac{B_{tb}-B_t}{D_{tb}-D_t}\right)^2$
Shear stress in flat plates	$B_s = F_{sy}\left[1+\frac{(F_{sy})^{1/3}}{17.7}\right]$	$D_s = \frac{B_s}{10}\left(\frac{B_s}{E}\right)^{1/2}$	$C_s = 0.41\frac{B_s}{D_s}$
Ultimate strength of flat plates in compression	$k_1 = 0.35, \quad k_2 = 2.27$		
Ultimate strength of flat plates in bending	$k_1 = 0.50, \quad k_2 = 2.04$		

* C_t can be found from a plot of curves of allowable stress based on elastic and inelastic buckling or by trial and error solution.

3.4 ALLOWABLE STRESSES

3.4.1 General Allowable stresses for aluminium alloy members shall be determined in accordance with provisions of Clauses 3.4.2 to 3.4.25.

In the formulas of Clauses 3.4.2 to 3.4.25, note the following:

(a) When more than one formula is given, the smallest of the resulting stresses should be used.

(b) The factors n_u, n_y and n_a shall be taken from Table 3.4(A).

(c) Values of coefficients k_t and k_c shall be taken from Table 3.4(B).

(d) Values of k_1 and k_2 are given in Tables 3.3(C) and 3.3(D).

The formulas are also listed in Table 3.4(C).

The allowable stresses for casting alloys for bridge type structures are given in Table 3.4(D).

TABLE 3.4(A)

FACTORS OF SAFETY

Factor of safety type	Building and similar type structures	Bridge and similar type structures
n_u	1.95	2.20
n_y	1.65	1.85
n_a	1.20	1.35

NOTE: Other factors of safety are given throughout this Standard.

TABLE 3.4(B)

VALUES OF COEFFICIENTS k_t AND k_c *

Alloy and temper	Non-welded or regions farther than 25 mm from a weld		Regions within 25 mm of a weld	
	k_t	k_c	k_t	k_c†
2014-T6, -T651‡ Alclad 2014-T6, -T651	1.25	1.12	—	—
6005-T5, 6061-T6, T651‡, 6063-T5, -T6, -T83 6105-T5, 6351-T5	1.0	1.12	1.0	1.0
All others listed in Table 3.3(A)	1.0	1.10	1.0	1.0

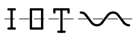
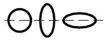
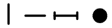
* These coefficients are used in the formulas in Table 3.4(C).

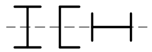
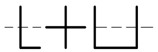
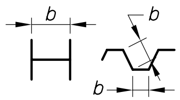
† If the weld compressive yield strength exceeds 0.9 times the parent material compressive yield strength, the allowable compressive stress within 25 mm of a weld shall be taken as equal to the allowable compressive stress for non-welded material.

‡ Values also apply to -T6510, -T6511 extrusion tempers.

TABLE 3.4(C)

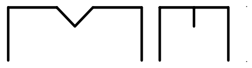
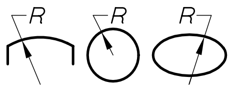
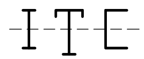
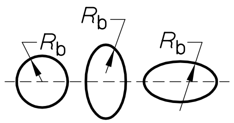
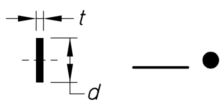
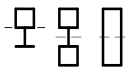
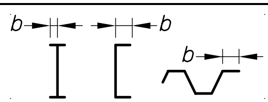
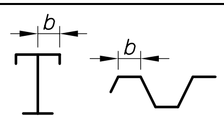
GENERAL FORMULAS FOR DETERMINING ALLOWABLE STRESSES FROM CLAUSE 3.4

Type of stress	Type of member or component		Clause	Allowable stress
Tension (axial, net section)	Any tension member		3.4.2	F_{ty}/n_y or $F_{tu}/(k_t n_u)$
Tension in beams (extreme fibre, net section)	Rectangular tubes, structural shapes bend around strong axis		3.4.3	F_{ty}/n_y or $F_{tu}/(k_t/n_u)$
	Round or oval tubes		3.4.4	$1.17F_{ty}/n_y$ or $1.24F_{tu}/(k_t/n_u)$
	Shapes bend about weak axis, bars, plates		3.4.5	$1.30F_{ty}/n_y$ or $1.42F_{tu}/(k_t/n_u)$
Bearing	On rivets and bolts		3.4.6	F_{by}/n_y or $F_{bu}/(1.2n_u)$
	On flat surfaces and pins and on bolts in slotted holes		3.4.7	$F_{by}/(1.5n_y)$ or $F_{bu}/(1.8n_u)$

Type of stress	Type of member or component		Clause	Allowable stress slenderness $\leq S_1$	Slenderness limit S_1 (see Note)	Allowable stress slenderness between S_1 and S_2	Slenderness limit S_2	Allowable stress slenderness $\geq S_2$
Compression in columns (axial, gross section)	All columns		3.4.8	$\frac{F_{cy}}{k_c n_y}$	$\frac{kL}{r} = \frac{B_c - \frac{n_u F_{cy}}{k_c n_y}}{D_c}$	$\frac{1}{n_u}\left(B_c - D_c \frac{kL}{r}\right)$	$\frac{kL}{r} = C_c$	$\frac{\pi^2 E}{n_u \left(\frac{kL}{r}\right)^2}$
Compression in components of columns (gross section)	Flat plates supported along one edge—columns buckling about a symmetry axis		3.4.9.1	$\frac{F_{cy}}{k_c n_y}$	$\frac{b}{t} = \frac{B_p - \frac{n_u F_{cy}}{k_c n_y}}{5.1D_p}$	$\frac{1}{n_u}\left(B_p - 5.1D_p \frac{b}{t}\right)$	$\frac{b}{t} = \frac{k_1 B_p}{5.1D_p}$	$\frac{k_2\sqrt{B_p E}}{n_u(5.1b/t)}$
	Flat plates supported along one edge—columns not buckling about a symmetry axis		3.4.9.2	$\frac{F_{cy}}{k_c n_y}$	$\frac{b}{t} = \frac{B_p - \frac{n_u F_{cy}}{k_c n_y}}{5.1D_p}$	$\frac{1}{n_u}\left(B_p - 5.1D_p \frac{b}{t}\right)$	$\frac{b}{t} = \frac{C_p}{5.1}$	$\frac{\pi^2 E}{n_u(5.1b/t)^2}$
	Flat plates with both edges supported		3.4.10.1	$\frac{F_{cy}}{k_c n_y}$	$\frac{b}{t} = \frac{B_p - \frac{n_u F_{cy}}{k_c n_y}}{1.6D_p}$	$\frac{1}{n_u}\left(B_p - 1.6D_p \frac{b}{t}\right)$	$\frac{b}{t} = \frac{k_1 B_p}{1.6D_p}$	$\frac{k_2\sqrt{B_p E}}{n_u(1.6b/t)}$
	Flat plates with one edge supported and other edge with stiffener		3.4.10.2	See Clause 3.4.10.2				

(*continued*)

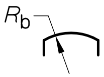
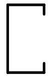
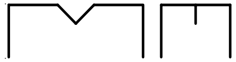
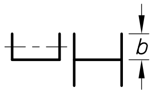
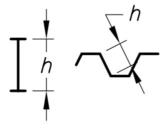
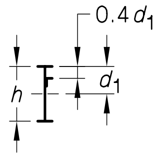
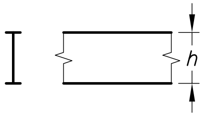
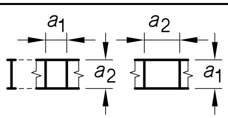
TABLE 3.4(C) *(continued)*

Type of stress	Type of member or component		Clause	Allowable stress slenderness $\leq S_1$	Slenderness Limit S_1 (see Note)	Allowable stress slenderness between S_1 and S_2	Slenderness limit S_2	Allowable stress slenderness $\geq S_2$
Compression in components of columns (gross section)	Flat plates with both edges supported and with an intermediate stiffener		3.4.10.3	See Clause 3.4.10.3				
	Curved plates supported on both edges, walls of round or oval tubes		3.4.11	$\dfrac{F_{cy}}{k_c n_y}$	$\dfrac{R}{t} = \left(\dfrac{B_t - \dfrac{n_u F_{cy}}{k_c n_y}}{D_t}\right)^2$	$\dfrac{1}{n_u}\left(B_t - D_t\sqrt{\dfrac{R}{t}}\right)$	$\dfrac{R}{t} = C_t$	$\dfrac{\pi^2 E}{16 n_u \left(\dfrac{R}{t}\right)\left(1 + \dfrac{\sqrt{R/t}}{35}\right)^2}$
Compression in beams (extreme fibre gross section)	Single web beams bent about strong axis		3.4.12	$\dfrac{F_{cy}}{n_y}$	$\dfrac{L_b}{r_y} = \dfrac{1.2(B_c - F_{cy})}{D_c}$	$\dfrac{1}{n_y}\left(B_c - \dfrac{D_c L_b}{1.2 r_y}\right)$	$\dfrac{L_b}{r_y} = 1.2 C_c$	$\dfrac{\pi^2 E}{n_y \left(\dfrac{L_b}{1.2 r_y}\right)^2}$
	Round or oval tubes		3.4.13*	$\dfrac{1.17 F_{cy}}{n_y}$	$\dfrac{R_b}{t} = \left(\dfrac{B_{tb} - 1.17 F_{cy}}{D_{tb}}\right)^2$	$\dfrac{1}{n_y}\left(B_{tb} - D_{tb}\sqrt{\dfrac{R_b}{t}}\right)$	$\dfrac{R_b}{t} = \left[\dfrac{\left(\dfrac{n_u}{n_y} B_{tb} - B_t\right)}{\left(\dfrac{n_u}{n_y} D_{tb} - D_t\right)}\right]^2$	Same as Clause 3.4.11
	Solid rectangular and round section beams		3.4.14	$\dfrac{1.3 F_{cy}}{n_y}$	$\dfrac{d}{t}\sqrt{\dfrac{L_b}{d}} = \dfrac{B_{br} - 1.3 F_{cy}}{2.3 D_{br}}$	$\dfrac{1}{n_y}\left(B_{br} - 2.3 D_{br}\dfrac{d}{t}\sqrt{\dfrac{L_b}{d}}\right)$	$\dfrac{d}{t}\sqrt{\dfrac{L_b}{d}} = \dfrac{C_{br}}{2.3}$	$\dfrac{\pi^2 E}{5.29 n_y \left(\dfrac{d}{t}\right)^2 \dfrac{L_b}{d}}$
	Rectangular tubes and box sections		3.4.15	$\dfrac{F_{cy}}{n_y}$	$\dfrac{L_b S_c}{0.5\sqrt{I_y J}} = \left(\dfrac{B_c - F_{cy}}{1.6 D_c}\right)^2$	$\dfrac{1}{n_y}\left(B_c - 1.6 D_c \sqrt{\dfrac{L_b S_c}{0.5\sqrt{I_y J}}}\right)$	$\dfrac{L_b S_c}{0.5\sqrt{I_y J}} = \left(\dfrac{C_c}{1.6}\right)^2$	$\dfrac{\pi^2 E}{2.56 n_y \left(\dfrac{L_b S_c}{0.5\sqrt{I_y J}}\right)}$
Compression in components of beams (component under uniform compression, gross section)	Flat plates supported on one edge		3.4.16	$\dfrac{F_{cy}}{n_y}$	$\dfrac{b}{t} = \dfrac{B_p - F_{cy}}{5.1 D_p}$	$\dfrac{1}{n_y}\left[B_p - 5.1 D_p\left(\dfrac{b}{t}\right)\right]$	$\dfrac{b}{t} = \dfrac{k_1 B_p}{5.1 D_p}$	$\dfrac{k_2\sqrt{B_p E}}{n_y (5.1 b/t)}$
	Flat plates with both edges supported		3.4.17	$\dfrac{F_{cy}}{n_y}$	$\dfrac{b}{t} = \dfrac{B_p - F_{cy}}{1.6 D_p}$	$\dfrac{1}{n_y}\left(B_p - 1.6 D_p\left(\dfrac{b}{t}\right)\right)$	$\dfrac{b}{t} = \dfrac{k_1 B_p}{1.6 D_p}$	$\dfrac{k_2\sqrt{B_p E}}{n_y (1.6 b/t)}$

(continued)

* For tubes with circumferential welds, equations of Clauses 3.4.11, 3.4.13 and 3.4.18 apply for $R/t \leq 20$.

TABLE 3.4(C) *(continued)*

Type of stress	Type of member or component	Clause	Allowable stress slenderness ≤ S_1	Slenderness Limit S_1 (see Note)	Allowable stress slenderness between S_1 and S_2	Slenderness limit S_2	Allowable stress slenderness ≥ S_2
Compression in components of beams (component under uniform compression, gross section)	Curved plates supported on both edges 	3.4.18*	$\frac{1.17F_{cy}}{n_y}$	$\frac{R_b}{t} = \left(\frac{B_t - 1.17F_{cy}}{D_p}\right)^2$	$\frac{1}{n_y}\left(B_t - D_t\sqrt{\frac{R_b}{t}}\right)$	$\frac{R_b}{t} = C_t$	$\frac{\pi^2 E}{16n_y\left(\frac{R_b}{t}\right)\left(1+\frac{\sqrt{R_b/t}}{35}\right)^2}$
	Flat plates with one edge supported and other edge with stiffener 	3.4.19	See Clause 3.4.19				
	Flat plates with both edges supported and with an intermediate stiffener 	3.4.20	See Clause 3.4.20				
Compression in components of beams (component under bending in own plane, gross section)	Flat plates with compression edge free, tension edge supported 	3.4.21	$\frac{1.3F_{cy}}{n_y}$	$\frac{b}{t} = \frac{B_{br} - 1.3F_{cy}}{3.5D_{br}}$	$\frac{1}{n_y}\left[B_{br} - 3.5D_{br}\left(\frac{h}{t}\right)\right]$	$\frac{b}{t} = \frac{C_{br}}{3.5}$	$\frac{\pi^2 E}{n_y(3.5b/t)^2}$
	Flat plate with both edges supported 	3.4.22	$\frac{1.3F_{cy}}{n_y}$	$\frac{h}{t} = \frac{B_{br} - 1.3F_{cy}}{0.67D_{br}}$	$\frac{1}{n_y}\left[B_{br} - 0.67D_{br}\left(\frac{h}{t}\right)\right]$	$\frac{h}{t} = \frac{k_1 B_{br}}{0.67D_{br}}$	$\frac{k_2\sqrt{B_{br}E}}{n_y(0.67h/t)}$
	Flat plate with horizontal stiffener, both edges supported 	3.4.23	$\frac{1.3F_{cy}}{n_y}$	$\frac{h}{t} = \frac{B_{br} - 1.3F_{cy}}{0.29D_{br}}$	$\frac{1}{n_y}\left[B_{br} - 0.29D_{br}\left(\frac{h}{t}\right)\right]$	$\frac{h}{t} = \frac{k_1 B_{br}}{0.29D_{br}}$	$\frac{k_2\sqrt{B_{br}E}}{n_y(0.29h/t)}$
Shear in webs (gross section)	Unstiffened flat webs 	3.4.24	$\frac{F_{sy}}{n_y}$	$\frac{h}{t} = \frac{B_s - F_{sy}}{1.25D_s}$	$\frac{1}{n_y}\left[B_s - 1.25D_s\left(\frac{h}{t}\right)\right]$	$\frac{h}{t} = \frac{C_s}{1.25}$	$\frac{\pi^2 E}{n_y(1.25h/t)^2}$
	Stiffened flat webs $a_e = a_1/\sqrt{1+0.7(a_1/a_2)^2}$ 	3.4.25	$\frac{F_{sy}}{n_y}$	$\frac{a_e}{t} = \frac{B_s - (n_a F_{sy}/n_y)}{1.25D_s}$	$\frac{1}{n_a}\left[B_s - 1.25D_s\left(\frac{a_e}{t}\right)\right]$	$\frac{a_e}{t} = \frac{C_s}{1.25}$	$\frac{\pi^2 E}{n_y(1.25a_e/t)^2}$

NOTE: For certain alloys and section specifications, a negative slenderness limit (S_1) may result. In such cases S_1 should be taken as 0.

TABLE 3.4(D)
ALLOWABLE STRESSES FOR BRIDGE TYPE STRUCTURES CASTING ALLOYS

Product	Permanent mold castings				Sand castings	
Alloy and temper	A444.0-T4	356.0-T6	356.0-T7	A356.0-T61	356.0T6	356.0-T7
Type of stress	Allowable stress, MPa					
Tension or compression* (either axial loading or bending)	41	55	48	62	41	41
	34	34	34	34	34	34
Shear*	28	34	31	41	28	28
	21	21	21	21	21	21
Bearing on rivets or bolts	72	97	86	110	72	72
	55	55	55	55	55	55
Bearing on flat surfaces and pins	48	66	55	72	48	48
	38	38	38	38	38	38

* Values given for compression and shear apply to parts that are sufficiently thick so that the slenderness S is less than the slenderness limit S_1 for alloy 6061-T6. Allowable compressive and shear stresses for parts with $S > S_1$ may be determined from the allowable stresses for highway structures of alloy 6061-T6 by means of the following formula:

$$F_{\text{cast}} = F_{6061} \times \frac{(F_{\text{cast}})_{\text{tc}}}{117}$$

where

F_{cast} = allowable compressive or shear stress on slender element for casting

F_{6061} = corresponding allowable stress for alloy 6060-T6

$(F_{\text{cast}})_{\text{tc}}$ = allowable tensile or compressive stress for casting from above table

WHITE ROWS	apply to nonwelded members and to welded members at locations farther than 25 mm from a weld	SHADED ROWS	apply within 25 mm of a weld

NOTE: For welding castings using 4043 filler metal for the alloys in Table 3.4(D), for some applications 4047 filler metal may be used.

3.4.2 Tension, axial, net section Calculation is as follows:

$$F = F_{ty}/n_y \qquad \ldots 3.4.2(1)$$

or

$$F = F_{tu}/(k_t n_u) \qquad \ldots 3.4.2(2)$$

Values of k_t are listed in Table 3.4(B). Values of n_u and n_y are listed in Table 3.4(A).

3.4.3 Tension in extreme fibres of beams—structural shapes bent about strong axis, rectangular tubes Calculation is as follows:

$$F = F_{ty}/n_y \qquad \ldots 3.4.3(1)$$

or

$$F = F_{tu}/(k_t n_u) \qquad \ldots 3.4.3(2)$$

3.4.4 Tension in extreme fibres of beams—round or oval tubes Calculation is as follows:

$$F = 1.17\, F_{ty}/n_y \qquad \ldots 3.4.4(1)$$

or

$$F = 1.24\, F_{tu}/(k_t n_u) \qquad \ldots 3.4.4(2)$$

3.4.5 Tension in extreme fibres of beams—shapes bent about weak axis, rectangular bars, solid round bars and plates Calculation is as follows:

$$F = 1.30\, F_{ty}/n_y \qquad \ldots 3.4.5(1)$$

or

$$F = 1.42\, F_{tu}/(k_t n_u) \qquad \ldots 3.4.5(2)$$

3.4.6 Bearing on rivets and bolts Calculation is as follows:

$$F = F_{by}/n_y \qquad \ldots 3.4.6(1)$$

or

$$F = F_{bu}/(1.2\ n_u) \qquad \ldots 3.4.6(2)$$

This value shall be used for a ratio of edge distance to fastener diameter of 2 or greater. For smaller ratios this allowable stress shall be multiplied by the ratio: (edge distance)(2 × fastener diameter). Edge distance is the distance from the centre of the fastener to the edge of the material in the direction of the applied load and shall not be less than 1.5 times the fastener diameter to extruded, sheared, sawed, rolled or planed edges.

3.4.7 Bearing on flat surfaces and pins and on bolts in slotted holes Calculation is as follows:

$$F = F_{by}/(1.5\ n_y) \qquad \ldots 3.4.7(1)$$

or

$$F = F_{bu}/(1.8\ n_u) \qquad \ldots 3.4.7(2)$$

3.4.8 Compression in columns, axial, gross section

3.4.8.1 *General* Calculation is as follows:

(a) $$F_c = \frac{F_{cy}}{k_c n_y} \qquad \ldots 3.4.8.1(1)$$

for $\frac{kL}{r}$ below slenderness limit S_1.

(b) $$F_c = \frac{1}{n_u}\left(B_c - D_c\frac{kL}{r}\right) \qquad \ldots 3.4.8.1(2)$$

for $\frac{kL}{r}$ between S_1 and S_2.

(c) $$F_c = \frac{\pi^2 E}{n_u\left(\frac{kL}{r}\right)^2} \qquad \ldots 3.4.8.1(3)$$

for $\frac{kL}{r}$ above S_2.

In Equations 3.4.8.1(1) to (3):

$$S_1 = \frac{B_c - \frac{n_u F_{cy}}{k_c n_y}}{D_c}$$

S_2 = C_c

k = the effective length factor by rational analysis. k shall be taken larger than or equal to unity unless rational analysis justifies a smaller value

L = the unsupported length

r = the radius of gyration of the column about the axis of buckling

3.4.8.2 *Sections not subject to torsional or torsional-flexural buckling* For closed cross-sections and other sections that are not subject to torsional or torsional-flexural buckling, $\frac{kL}{r}$ shall be the largest slenderness ratio for flexural buckling of the column.

3.4.8.3 *Doubly or singly symmetric sections subject to torsional or torsional-flexural buckling* For doubly or singly symmetric sections subject to torsional or torsional-flexural buckling $\frac{kL}{r}$ shall be the larger of the largest slenderness ratio for flexural buckling and the equivalent slenderness ratio determined for torsional-flexural buckling as follows:

$$\left(\frac{kL}{r}\right)_e = \pi\sqrt{\frac{E}{F_e}} \qquad \ldots 3.4.8.3(1)$$

where F_e is the elastic critical stress determined as follows:

For torsional buckling:

$$F_e = F_{tb} \qquad \ldots 3.4.8.3(2)$$

For torsional-flexural buckling:

$$F_e = \frac{1}{2\beta}\left[(F_{ex} + F_{tb}) - \sqrt{(F_{ex} + F_{tb})^2 - 4\beta F_{ex}F_{tb}}\right] \qquad \ldots 3.4.8.3(3)$$

Alternatively, for torsional-flexural buckling, a conservative estimate of F_e shall be permitted to be obtained as follows:

$$F_e = \frac{F_{ex}F_{tb}}{F_{ex} + F_{tb}} \qquad \ldots 3.4.8.3(4)$$

In Equations 3.4.8.3(1) to (4):

x-axis is the centroidal symmetry axis

A = full cross-sectional area

C_w = torsional warping constant of the cross-section

E = compressive modulus of elasticity (See Table 3.3(A))

$$F_{ex} = \frac{\pi^2 E}{\left(\frac{k_x L_b}{r_x}\right)^2}$$

$$F_{tb} = \frac{1}{A r_o^2}\left(GJ + \frac{\pi^2 E C_w}{(k_o L_t)^2}\right)$$

G = shear modulus = 3/8 E

J = torsion constant

k_x = effective length coefficient for buckling about the x-axis

k_o = effective length coefficient for torsional buckling. k_o shall be taken larger than or equal to unity unless rational analysis justifies a smaller value

L_t = unbraced length for twisting

L_b = unbraced length for bending about the x-axis

$$r_o = \sqrt{r_x^2 + r_y^2 + x_o^2}$$

polar radius of gyration of the cross-section about the shear centre

r_x, r_y = radii of gyration of the cross-section about the centroidal principal axes

x_o = x-coordinate of the shear centre

β = $1 - (x_o/r_o)^2$

3.4.8.4 *Nonsymmetric sections subject to torsional or torsional-flexural buckling* For nonsymmetric section subject to torsional or torsional-flexural buckling $\frac{kL}{r}$ shall be determined by rational analysis.

3.4.9 Uniform compression in components of columns—buckling axis

3.4.9.1 *Uniform compression in components of columns whose buckling axis is an axis of symmetry—flat plates supported along one edge* Calculation is as follows:

(a) $$F_c = \frac{F_{cy}}{k_c n_y} \qquad \ldots 3.4.9.1(1)$$

for b/t less than slenderness limit S_1.

(b) $$F_c = \frac{1}{n_u}\left(B_p - 5.1 D_p \frac{b}{t}\right) \qquad \ldots 3.4.9.1(2)$$

for b/t between S_1 and S_2.

(c) $$F_c = \frac{k_2 \sqrt{B_p E}}{n_u (5.1\, b/t)} \qquad \ldots 3.4.9.1(3)$$

for b/t greater than S_2.

In Equations 3.4.9(1) to (3):

$$S_1 = \frac{B_p - \dfrac{n_u F_{cy}}{k_c n_y}}{5.1 D_p}$$

$$S_2 = \frac{k_1 B_p}{5.1 D_p}$$

b = distance from unsupported edge of element to toe of the fillet or bend, except if the inside corner radius exceeds 4 times the thickness; then the inside radius shall be assumed equal to 4 times the thickness in calculating b. Plate width b is illustrated in Figure 3.4.9.2.

3.4.9.2 *Uniform compression in components of columns whose buckling axis is not an axis of symmetry—flat plates supported along one edge* Calculation is as follows:

(a) $$F_c = \frac{F_{cy}}{k_c n_y} \qquad \ldots 3.4.9.2(1)$$

for b/t less than slenderness limit S_1.

(b) $$F_c = \frac{1}{n_u}\left(B_p - 5.1 D_p \frac{b}{t}\right) \qquad \ldots 3.4.9.2(2)$$

for b/t between S_1 and S_2.

(c) $$F_c = \frac{\pi^2 E}{n_u (5.1\, b/t)^2} \qquad \ldots 3.4.9.2(3)$$

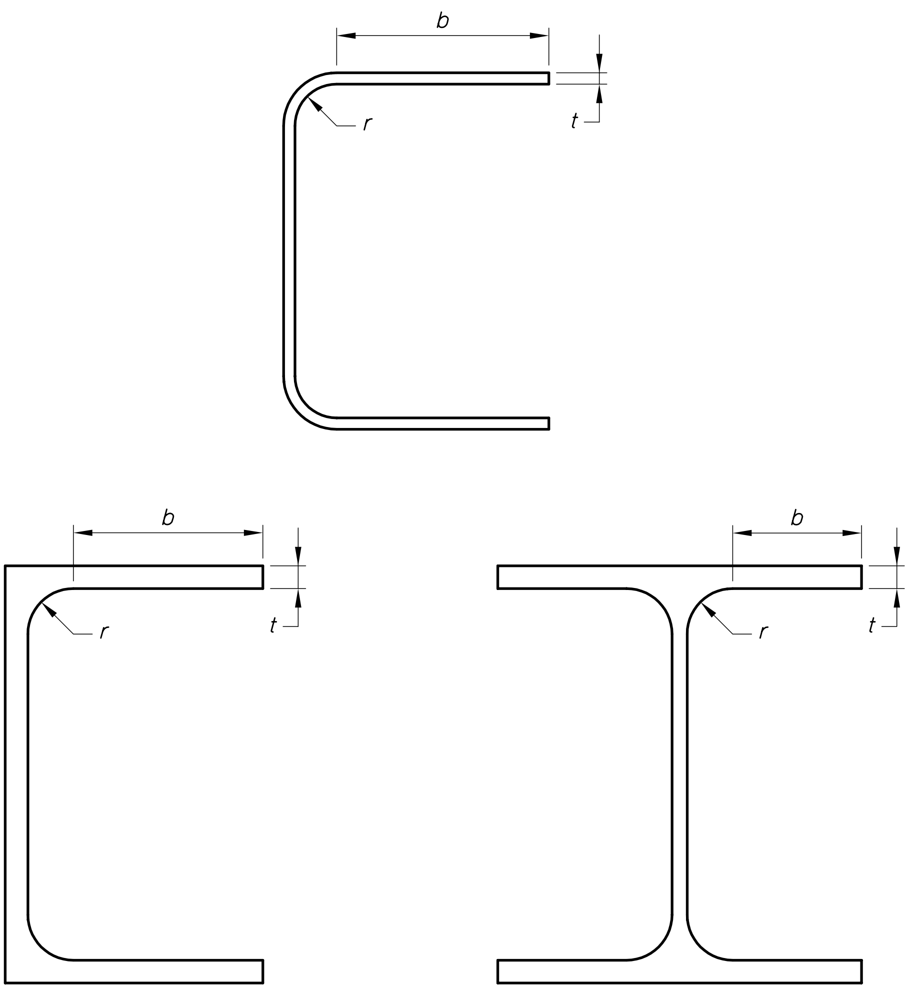
for b/t greater than S_2.

In Equations 3.4.9.2(1) to (3):

$$S_1 = \frac{B_p - \dfrac{n_u F_{cy}}{k_c n_y}}{5.1 D_p}$$

$$S_2 = \frac{C_p}{5.1}$$

b = distance from unsupported edge of element to toe of the fillet or bend, except if the inside corner radius exceeds 4 times the thickness; then the inside radius shall be assumed equal to 4 times the thickness in calculating b. Plate width b is illustrated in Figure 3.4.9.2.



NOTE: If the inside corner radius exceeds 4 times the thickness then the inside radius shall be assumed to be equal to 4 times the thickness in calculating b.

FIGURE 3.4.9.2 FLAT PLATES SUPPORTED ALONG ONE EDGE

3.4.10 Uniform compression in components of columns, gross section—flat plates

3.4.10.1 *Uniform compression in components of columns, gross section—flat plates with both edges supported* Calculation is as follows:

(a) $$F_c = \frac{F_{cy}}{k_c n_y} \qquad \text{. . .3.4.10.1(1)}$$

for b/t less than slenderness limit S_1.

(b) $$F_c = \frac{1}{n_u}\left(B_p - 1.6 D_p \frac{b}{t}\right) \qquad \text{. . . 3.4.10.1(2)}$$

for b/t between S_1 and S_2.

(c) $$F_c = \frac{k_2\sqrt{B_p E}}{n_u(1.6\,b/t)} \qquad \text{. . . 3.4.10.1(3)}$$

for b/t greater than S_2.

In Equations 3.4.10.1(1) to (3):

$$S_1 = \frac{B_p - \dfrac{n_u F_{cy}}{k_c n_y}}{1.6 D_p}$$

$$S_2 = \frac{k_1 B_p}{1.6 D_p}$$

b = distance between the toe of the fillet or bends. If the inside corner radius exceeds 4 times the thickness then the inside radius shall be assumed equal to 4 times the thickness in calculating b. Plate width b is illustrated in Figure 3.4.10.1.

3.4.10.2 *Uniform compression in components of columns—flat plates with one edge supported and other edge with stiffener* The following shall apply when $D_s/b \le 0.8$:

$$F_c = \frac{F_{cy}}{k_c n_y} \qquad \text{. . . 3.4.10.2(1)}$$

or

$$F_c = F_{UT} + (F_{ST} - F_{UT})R \le F_{ST} \qquad \text{. . . 3.4.10.2(2)}$$

For a simple straight lip stiffener of constant thickness, F_c shall not exceed the allowable stress for the stiffener according to Clause 3.4.9.1.

In Equations 3.4.10.2(1) and (2)

D_s is as defined in Figures 3.4.10.2(A) and (B)

F_{UT} = allowable stress according to Clause 3.4.9.1, neglecting the stiffener

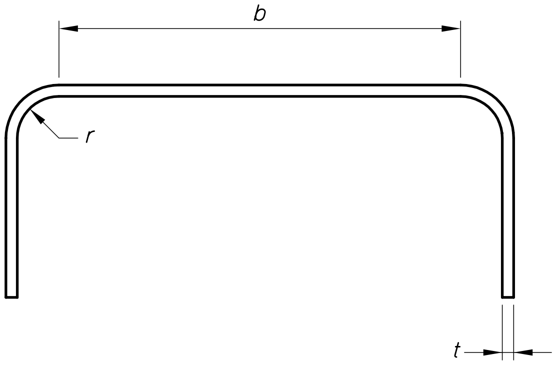
F_{ST} = allowable stress according to Clause 3.4.10.1

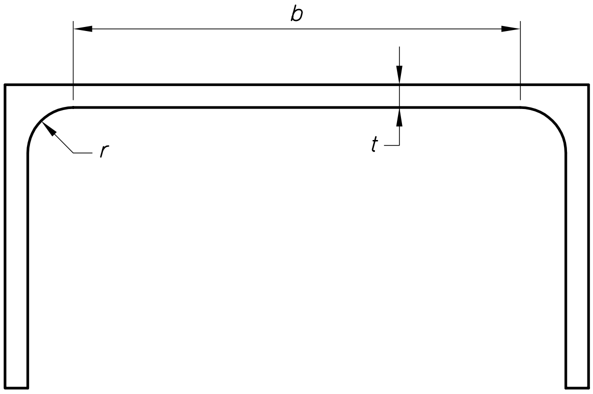
R = ratio to be determined as follows:

$$R = 1.0 \qquad \text{for } b/t \le S/3 \qquad \text{. . . 3.4.10.2(3)}$$

$$R = \frac{r_s}{9t\left(\dfrac{b/t}{S} - \dfrac{1}{3}\right)} \le 1.0 \qquad \text{for } S/3 < b/t \le S \qquad \text{. . . 3.4.10.2(4)}$$

$$R = \frac{r_s}{1.5t\left(\dfrac{b/t}{S}+3\right)} \leq 1.0 \quad \text{for } 2S > b/t > S \qquad \ldots 3.4.10.2(5)$$





NOTE: If the inside corner radius exceeds 4 times the thickness then the inside radius shall be assumed to be equal to 4 times the thickness in calculating *b*.

FIGURE 3.4.10.1 FLAT PLATES WITH BOTH EDGES SUPPORTED

where

r_s = radius of gyration of the stiffener determined as follows:

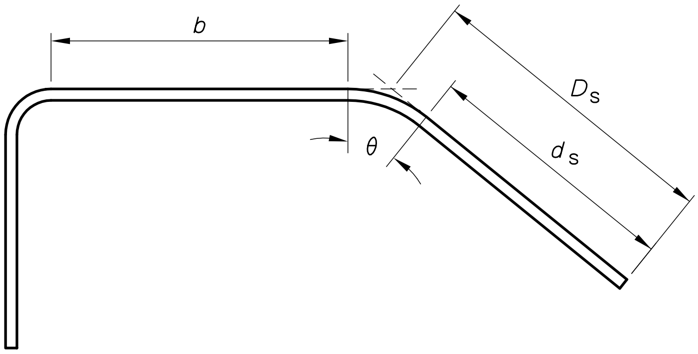
- for simple straight lip stiffeners of constant thickness similar to that shown in Figure 3.4.10.2(A), r_s shall be calculated as—

$$r_s = \frac{d_s \sin\theta}{\sqrt{3}} \qquad \ldots 3.4.10.2(6)$$

- for other types of stiffeners, such as shown in Figure 3.4.10.2(B), r_s shall be calculated about the mid-thickness of the flange being stiffened

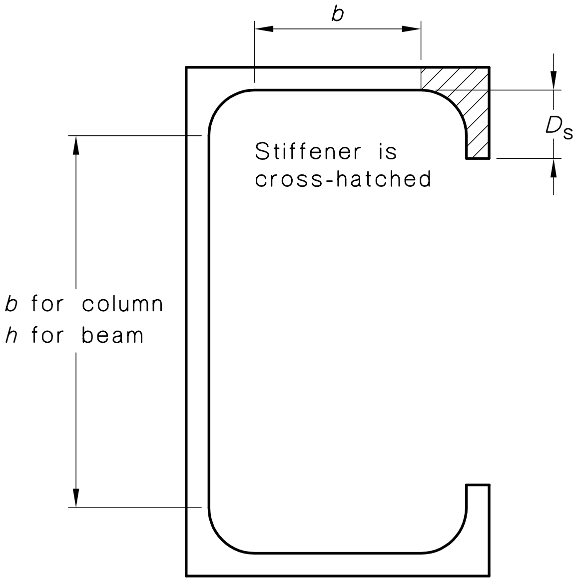
$$S = 128\sqrt{\frac{E}{F_{cy}}} \qquad \ldots 3.4.10.2(7)$$

b = distance from unsupported edge of the element to toe of the fillet or bend. If the inside corner radius exceeds 4 times the thickness then the inside radius shall be assumed equal to 4 times the thickness in calculating b. Plate width b is illustrated in Figures 3.4.10.2(A) and (B).



NOTE: If the inside corner radius exceeds 4 times the thickness then the inside radius shall be assumed to be equal to 4 times the thickness in calculating *b*.

FIGURE 3.4.10.2(A) EDGE STIFFENED ELEMENTS



NOTE: If the inside corner radius exceeds 4 times the thickness then the inside radius shall be assumed to be equal to 4 times the thickness in calculating *b*.

FIGURE 3.4.10.2(B) EDGE STIFFENED ELEMENTS

3.4.10.3 *Uniform compression in components of columns—flat plates with both edges supported and with an intermediate stiffener* Calculation is as follows:

(a) $$F_c = \frac{F_{cy}}{k_c n_y} \quad \ldots 3.4.10.3(1)$$

for λ_s less than slenderness limit S_1.

(b) $$F_c = \frac{1}{n_u}(B_c - D_c\lambda_s) \quad \ldots 3.4.10.3(2)$$

for λ_s between S_1 and S_2.

(c) $$F_c = \frac{\pi^2 E}{n_u \lambda_s^2}$$ . . . 3.4.10.3(3)

for values of λ_s greater than S_2.

The allowable stress F_c obtained above shall not be more than the allowable stress accordingly to Clause 3.4.10.1 for the component plate elements of the intermediately stiffened element.

The allowable stress F_c obtained above shall not be less than that determined according to Clause 3.4.10.1 ignoring the intermediate stiffener.

In Equations 3.4.10.3(1) to (3):

A_s = area of the stiffener

I_o = moment of inertia of a section comprising the stiffener and one half of the width of the adjacent plate elements and the transition corners between them taken about the centroidal axis of the section parallel to the flat plate element that is stiffened (Figure 3.4.10.3).

$$S_1 = \frac{B_c - \dfrac{n_u F_{cy}}{k_c n_y}}{D_c}$$ . . . 3.4.10.3(4)

$$S_2 = C_c$$ . . . 3.4.10.3(5)

$$\lambda_s = 4.62\left(\frac{b}{t}\right)\sqrt{\frac{1 + \dfrac{A_s}{b_t}}{1 + \sqrt{1 + \dfrac{10.67 I_o}{b t^3}}}}$$ . . . 3.4.10.3(6)

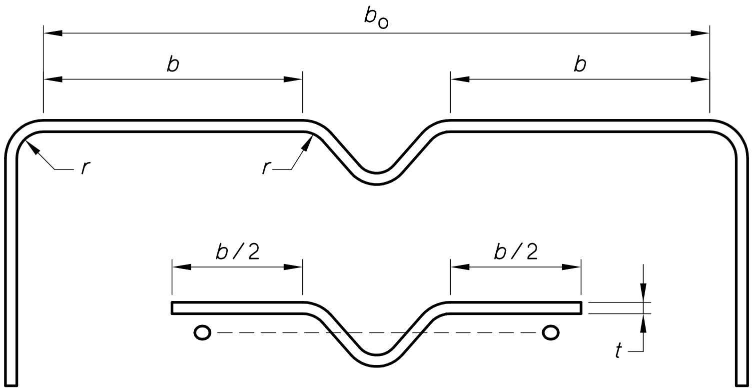
3.4.11 Uniform compression in components of columns, gross section—curved plates supported on both edges, walls round or oval tubes Calculation is as follows:

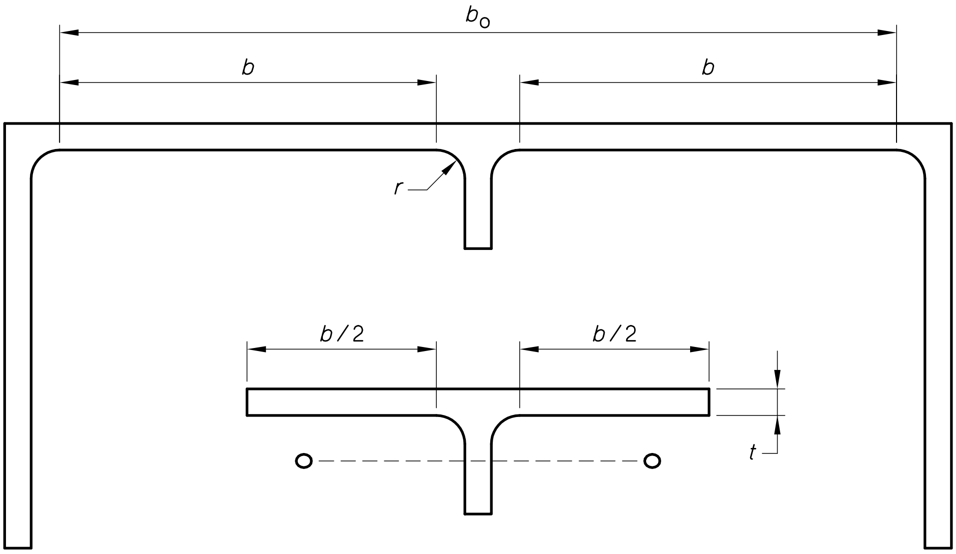
(a) $$F_c = \frac{F_{cy}}{k_c n_y}$$ . . . 3.4.11(1)

for R/t below slenderness limit S_1.

(b) $$F_c = \frac{1}{n_u}\left(B_t - D_t\sqrt{\frac{R_m}{t}}\right)$$ . . . 3.4.11(2)

for R_m/t between S_1 and S_2.





NOTES:

1 Line o–o is the neutral axis of the stiffener and plate of width $b/2$ on each side of the stiffener. I_o is the moment of inertia of the portion shown in the partial section.

2 If the inside corner radius exceeds 4 times the thickness then the inside radius shall be assumed to be equal to 4 times the thickness in calculating b.

FIGURE 3.4.10.3 PLATE ELEMENTS WITH INTERMEDIATE STIFFENERS

(c) $$F_c = \frac{\pi^2 E}{16 n_u \left(\frac{R_m}{t}\right)\left(1 + \frac{\sqrt{R_m/t}}{35}\right)^2} \qquad \ldots 3.4.11(3)$$

for R_m/t greater than S_2.

In Equations 3.4.11(1) to (3):

R_m = mid-thickness radius of round tubular column or maximum mid-thickness radius of oval tubular column

$$S_1 = \left(\frac{B_t - \frac{n_u F_{cy}}{k_c n_y}}{D_t}\right)^2$$

$S_2 = C_t$

For tubes with circumferential welds, the equations of this Clause apply for $R_m/t \leq 20$.

3.4.12 Compression in beams, extreme fibre, gross section—single web beams bent about strong axis: Calculation is as follows:

(a) $$F_c = \frac{F_{cy}}{n_y} \quad \text{. . . 3.4.12(1)}$$

for L_b/r_y below slenderness limit S_1.

(b) $$F_c = \frac{1}{n_y}\left(B_c - \frac{D_c L_b}{1.2 r_y}\right) \quad \text{. . . 3.4.12(2)}$$

for L_b/r_y between S_1 and S_2.

(c) $$F_c = \frac{\pi^2 E}{n_y \left(\frac{L_b}{1.2 r_y}\right)^2} \quad \text{. . . 3.4.12(3)}$$

for L_b/r_y greater than S_2.

In Equations 3.4.12(1) to (3):

$$S_1 = \frac{1.2(B_c - F_{cy})}{D_c}$$

$S_2 = 1.2C_c$

r_y = radius of gyration of a beam (about axis parallel to web). (For beams that are unsymmetrical about the horizontal axis, r_y shall be calculated as though both flanges were the same as the compression flange)

L_b = length of the beam between bracing points or between a brace point and the free end of a cantilever beam. Bracing points are the points at which the compression flange is restrained against lateral movement or twisting

The effect of the variation of the moment in the span is accounted for by replacing L_b by $L_b/\sqrt{C_b}$ in the equations and limits specified in this Clause. The values of C_b are given in Clause 4.9.5.1.

A more accurate value of F_c is obtained by replacing r_y by the effective value denoted r_{ye} given in Clause 4.9.1.

3.4.13 Compression in beams, extreme fibre, gross section—round or oval tubes Calculation is as follows:

(a) $$F_c = \frac{1.17 F_{cy}}{n_y} \quad \text{. . . 3.4.13(1)}$$

for R_b/t below slenderness limit S_1.

(b) $$F_c = \frac{1}{n_y}\left(B_{tb} - D_{tb}\sqrt{\frac{R_b}{t}}\right) \quad \text{. . . 3.4.13(2)}$$

for R_b/t between S_1 and S_2.

(c) For R_b/t values greater than S_2, the allowable bending stress shall be determined from the formulas for tubes in compression in Clause 3.4.11 using the formula that is appropriate for the particular value of R_b/t.

In Equations 3.4.13(1) and (2):

R_b = mid-thickness radius of curvature of tubular elements

$$S_1 = \left(\frac{B_{tb} - 1.17F_{cy}}{D_{tb}}\right)^2$$

$$S_2 = \left(\frac{\frac{n_u}{n_y}B_{tb} - B_t}{\frac{n_u}{n_y}D_{tb} - D_t}\right)^2$$

For tubes with circumferential welds, the equations of this Clause apply for $R_b/t \le 20$.

3.4.14 Compression in beams, extreme fibre, gross section—solid rectangular and round section beams Calculation is as follows:

(a) $$F_c = \frac{1.30F_{cy}}{n_y} \quad \text{. . . 3.4.14(1)}$$

for solid round section beams of any length and for rectangular section with $\frac{d}{t}\sqrt{\frac{L_b}{d}}$ below slenderness limit S_1.

(b) $$F_c = \frac{1}{n_y}\left(B_{br} - 2.3D_{br}\frac{d}{t}\sqrt{\frac{L_b}{d}}\right) \quad \text{. . . 3.4.14(2)}$$

for rectangular sections with $\frac{d}{t}\sqrt{\frac{L_b}{d}}$ between S_1 and S_2.

(c) $$F_c = \frac{\pi^2 E}{5.29n_y\left(\frac{d}{t}\right)^2\frac{L_b}{d}} \quad \text{. . . 3.4.14(3)}$$

for rectangular sections with $\frac{d}{t}\sqrt{\frac{L_b}{d}}$ values greater than S_2.

In Equations 3.4.14(1) to (3):

d = depth of section or beam

L_b = length of the beam between bracing points or between a brace point and the free end of a cantilever beam. Bracing points are the points at which the compression flange is restrained against lateral movement or twisting

$$S_1 = \frac{B_{br} - 1.3F_{cy}}{2.3D_{br}}$$

$$S_2 = \frac{C_{br}}{2.3}$$

The effect of the variation of the moment in the span is accounted for by replacing L_b by L_b/C_b in the equations and limits specified in this Clause. The values of C_b are given in Clause 4.9.5.

3.4.15 Compression in beams, extreme fibre, gross section—rectangular tubes, box sections and beams having sections containing tubular portions Calculation is as follows:

(a) $$F_c = \frac{F_{cy}}{n_y} \qquad \ldots 3.4.15(1)$$

for $\dfrac{L_b S_c}{0.5\sqrt{I_y J}}$ below slenderness limit S_1.

(b) $$F_c = \frac{1}{n_y}\left(B_c - 1.6 D_c \sqrt{\frac{L_b Z_c}{0.5\sqrt{I_y J}}}\right) \qquad \ldots 3.4.15(2)$$

for $\dfrac{L_b Z_c}{0.5\sqrt{I_y J}}$ between S_1 and S_2.

(c) $$F_c = \frac{\pi^2 E}{2.56 n_y \left(\dfrac{L_b Z_c}{0.5\sqrt{I_y J}}\right)} \qquad \ldots 3.4.15(3)$$

for $\dfrac{L_b Z_c}{0.5\sqrt{I_y J}}$ greater than S_2.

In Equations 3.4.15(1) to (3):

I_y = moment of inertia of a beam about axis parallel to web

J = torsion constant

L_b = length of the beam between bracing points or between a brace point and the free end of a cantilever beam. Bracing points are the points at which the compression flange is restrained against lateral movement or twisting

$$S_1 = \left(\frac{B_c - F_{cy}}{1.6 D_c}\right)^2$$

$$S_2 = \left(\frac{C_c}{1.6}\right)^2$$

The effect of the variation of the moment in the span is accounted for by replacing L_b by L_b/C_b in the equations and limits specified in this Clause. The values of C_b are given in Clause 4.9.5.

A more accurate value of F_c is obtained by using the equations in Clause 3.4.12 and replacing r_y by the effective value denoted r_{ye} given in Clause 4.9.

For narrow rectangular tubes $0.5\sqrt{I_y J}$ is permitted to be replaced by I_y.

3.4.16 Compression in components of beams (component under uniform compression), gross section—flat plates supported along one edge Calculation is as follows:

(a) $$F_c = \frac{F_{cy}}{n_y}$$ . . . 3.4.16(1)

for b/t below slenderness limit S_1.

(b) $$F_c = \frac{1}{n_y}\left[B_p - 5.1 D_p\left(\frac{b}{t}\right)\right]$$ . . . 3.4.16(2)

for b/t between S_1 and S_2.

(c) $$F_c = \frac{k_2\sqrt{B_p E}}{n_y(5.1\, b/t)}$$ . . . 3.4.16(3)

for b/t greater than S_2.

In Equations 3.4.16(1) to (3):

$$S_1 = \frac{B_p - F_{cy}}{5.1 D_p}$$

$$S_2 = \frac{k_1 B_p}{5.1 D_p}$$

b = distance from unsupported edge of element to toe of the fillet or bend, except if the inside corner radius exceeds 4 times the thickness; then the inside radius shall be assumed equal to 4 times the thickness in calculating b. Plate width b is illustrated in Figure 3.4.9.2.

3.4.17 Compression in components of beams (component under uniform compression), gross section—flat plates with both edges supported Calculation is as follows:

(a) $$F_c = \frac{F_{cy}}{n_y}$$ . . . 3.4.17(1)

for b/t below slenderness limit S_1.

(b) $$F_c = \frac{1}{n_y}\left[B_p - 1.6 D_p\left(\frac{b}{t}\right)\right]$$ . . . 3.4.17(2)

for b/t between S_1 and S_2.

(c) $$F_c = \frac{k_2\sqrt{B_p E}}{n_y(1.6\, b/t)}$$ . . . 3.4.17(3)

for b/t greater than S_2.

In Equations 3.4.17(1) to (3):

$$S_1 = \frac{B_p - F_{cy}}{1.6 D_p}$$

$$S_2 = \frac{k_1 B_p}{1.6 D_p}$$

b = distance between the toe of the fillets or bends. If the inside corner radius exceeds 4 times the thickness then the inside radius shall be assumed equal to 4 times the thickness in calculating b. Plate width b is illustrated in Figure 3.4.10.1.

3.4.18 Uniform compression in components of beams—curved plates with both edges supported Calculation is as follows:

(a) $$F_c = \frac{1.17 F_{cy}}{n_y} \qquad \ldots 3.4.18(1)$$

for R_b/t below slenderness limit S_1.

(b) $$F_c = \frac{1}{n_y}\left(B_t - D_t\sqrt{\frac{R_b}{t}}\right) \qquad \ldots 3.4.18(2)$$

for R_b/t between S_1 and S_2.

(c) $$F_c = \frac{\pi^2 E}{16 n_y\left(\frac{R_b}{t}\right)\left(1 + \frac{\sqrt{R_b/t}}{35}\right)^2} \qquad \ldots 3.4.18(3)$$

for R_b/t greater than S_2.

In Equations 3.4.18(1) to (3):

R_b = radius of curvature to mid-thickness of section

$$S_1 = \left(\frac{B_t - 1.17 F_{cy}}{D_t}\right)^2$$

S_2 = C_t

C_t can be found from a plot of the curves of allowable stress for values of R_b/b less than and greater than S_2 or by a trial and error solution.

For tubes with circumferential welds, the equations of this Clause apply for $R_b/b \leq 20$.

3.4.19 Uniform compression in components of beams—flat plates with one edge supported and other edge with stiffener The following shall apply when $D_s/b \leq 0.8$:

$$F_c = \frac{F_{cy}}{n_y} \qquad \ldots 3.4.19(1)$$

or $$F_c = F_{UT} + (F_{ST} - F_{UT})R \leq F_{ST} \qquad \ldots 3.4.19(2)$$

For a simple straight lip edge stiffener of constant thickness, F_c shall not exceed the allowable stress for the stiffener according to Clause 3.4.9.

In Equations 3.4.19(1) to (3):

D_s = defined in Figures 3.4.10.2(A) and (B)

F_{UT} = allowable stress according to Clause 3.4.16, neglecting the stiffener

F_{ST} = allowable stress according to Clause 3.4.17

R = ratio to be determined as follows:

$R = 1.0$ for $b/t \leq S/3$

$$R = \frac{r_s}{9t\left(\frac{b/t}{S} - \frac{1}{3}\right)} \leq 1.0 \quad \text{for } S/3 < b/t \leq S$$

$$R = \frac{r_s}{1.5t\left(\frac{b/t}{S} + 3\right)} \leq 1.0 \quad \text{for } 2S > b/t \leq S$$

r_s = Radius of gyration of the stiffener determined as follows:

- for simple straight lip stiffeners of constant thickness similar to that shown in Figure 3.4.10.2(A), r_s shall be calculated as:

$$r_s = \frac{d \sin\theta}{\sqrt{3}}$$

- for other type stiffeners, r_s shall be calculated about the mid-thickness of the flat plate element being stiffened

S $= 1.28 = \sqrt{\frac{E}{F_{cy}}}$

b = distance from unsupported edge of element to toe of the fillet or bend, except if the inside corner radius exceeds 4 times the thickness; then the inside radius shall be assumed equal to 4 times the thickness in calculating b. Plate width b is illustrated in Figure 3.4.10.1.

3.4.20 Uniform compression in components of beams—flat plates with both edges supported and with an intermediate stiffener Calculation is as follows:

(a) $$F_c = \frac{F_{cy}}{n_y} \qquad \text{. . . 3.4.20(1)}$$

for λ_s less than slenderness limit S_1.

(b) $$F_c = \frac{1}{n_y}(B_c - D_c\lambda_s) \qquad \text{. . . 3.4.20(2)}$$

for λ_s between S_1 and S_2.

(c) $$F_c = \frac{\pi^2 E}{n_y \lambda_s^2} \qquad \text{. . . 3.4.20(3)}$$

for λ_s greater than S_2.

The allowable stress F_c obtained above shall not be more than the allowable stress according to Clause 3.4.17, for the component plate elements of the intermediately stiffened element.

The allowable stress F_c obtained above shall not be less than that determined according to Clause 3.4.17, ignoring the intermediate stiffener or component elements of the stiffener.

In Equations 3.4.20(1) to (3):

A_s = area of the stiffener

I_o = moment of inertia of a section comprising the stiffener and one half of the width of the adjacent plate elements and the transition corners between them taken about the centroidal axis of the section parallel to the flat plate element that is stiffened (Figure 3.4.10.3)

$$S_1 = \frac{B_c - F_{cy}}{D_c} \quad \ldots 3.4.20(4)$$

$$S_2 = C_c \quad \ldots 3.4.20(5)$$

$$\lambda_s = 4.62\left(\frac{b}{t}\right)\sqrt{\frac{1 + \dfrac{A_s}{bt}}{1 + \sqrt{1 + \dfrac{10.67 I_o}{bt^3}}}} \quad \ldots 3.4.20(6)$$

3.4.21 Compression in components of beams (component under bending in own plane), gross section—flat plates with compression edge free, tension edge supported Calculation is as follows:

(a) $$F_c = \frac{1.3 F_{cy}}{n_y} \quad \ldots 3.4.21(1)$$

for b/t below slenderness limit S_1.

(b) $$F_c = \frac{1}{n_y}\left[B_{br} - 3.5 D_{br}\left(\frac{b}{t}\right)\right] \quad \ldots 3.4.21(2)$$

for b/t between S_1 and S_2.

(c) $$F_c = \frac{\pi^2 E}{n_y (3.5 b/t)^2} \quad \ldots 3.4.21(3)$$

for b/t greater than S_2.

In Equations 3.4.21(1) to (3):

$$S_1 = \frac{B_{br} - 1.3 F_{cy}}{3.5 D_{br}}$$

$$S_2 = \frac{C_{br}}{3.5}$$

3.4.22 Compression in components of beams (component under bending in own plane), gross section—flat plates with both edges supported Calculation is as follows:

(a) $$F_c = \frac{1.3 F_{cy}}{n_y} \quad \ldots 3.4.22(1)$$

for h/t below slenderness limit S_1.

(b) $$F_c = \frac{1}{n_y}\left[B_{br} - 0.67 D_{br}\left(\frac{h}{t}\right)\right] \quad \ldots 3.4.22(2)$$

for h/t between S_1 and S_2.

(c) $$F_c = \frac{k_2\sqrt{B_{br} E}}{n_y (0.67 h/t)} \quad \ldots 3.4.22(3)$$

for h/t greater than S_2.

In Equations 3.4.22(1) to (3):

h = clear web height (shown in Figure 3.4.22)

$$S_1 = \frac{B_{br} - 1.3F_{cy}}{0.67D_{br}}$$

$$S_2 = \frac{k_1 B_{br}}{0.67D_{br}}$$

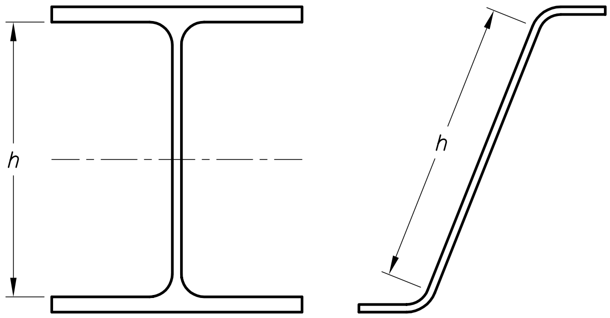


FIGURE 3.4.22 DIMENSIONAL NOTATION

3.4.23 Compression in components of beam (component under bending in own plane), gross section—flat plates with horizontal stiffener, both edges supported The following shall apply for stiffeners located at 0.4 d_1 from the flange as shown in Figure 3.4.23.

(a) $$F_c = \frac{1.3F_{cy}}{n_y} \qquad \ldots 3.4.23(1)$$

for h/t below slenderness limit S_1.

(b) $$F_c = \frac{1}{n_y}\left[B_{br} - 0.29D_{br}\left(\frac{h}{t}\right)\right] \qquad \ldots 3.4.23(2)$$

for h/t between S_1 and S_2.

(c) $$F_c = \frac{k_2\sqrt{B_{br}E}}{n_y(0.29h/t)} \qquad \ldots 3.4.23(3)$$

for h/t greater than S_2.

In Equations 3.4.23(1) to (3):

$$S_1 = \frac{B_{br} - 1.3F_{cy}}{0.29D_{br}}$$

$$S_2 = \frac{k_1 B_{br}}{0.29D_{br}}$$

h = clear web height (shown in Figure 3.4.23)

d_1 = clear distance from the neutral axis to the compression flange (shown in Figure 3.4.23)

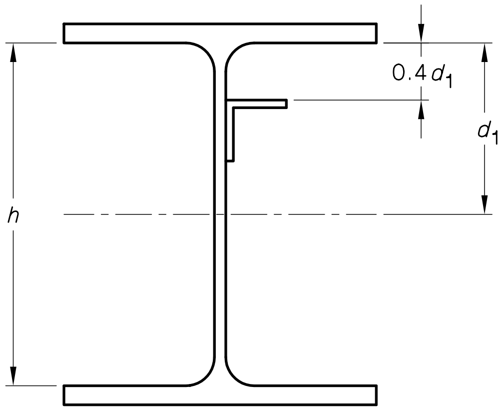


FIGURE 3.4.23 DIMENSIONS h AND d_1

3.4.24 Shear in webs—unstiffened flat webs Calculation is as follows:

(a) $$F_s = \frac{F_{sy}}{n_y} \quad \ldots 3.4.24(1)$$

for h/t below slenderness limit S_1.

(b) $$F_s = \frac{1}{n_y}\left[B_s - 1.25 D_s\left(\frac{h}{t}\right)\right] \quad \ldots 3.4.24(2)$$

for h/t between S_1 and S_2.

(c) $$F_c = \frac{\pi^2 E}{n_y(1.25 h/t)^2} \quad \ldots 3.4.24(3)$$

for h/t greater than S_2.

In Equations 3.4.24(1) to 3:

h = clear web height (shown in Figure 3.4.23)

$$S_1 = \frac{B_s - F_{sy}}{1.25 D_s}$$

$$S_2 = \frac{C_s}{1.25}$$

3.4.25 Shear in webs—stiffened flat webs Calculation is as follows:

(a) $$F_s = \frac{F_{sy}}{n_y} \quad \ldots 3.4.25(1)$$

for a_e/t below slenderness limit S_1.

(b) $$F_s = \frac{1}{n_a}\left[B_s - 1.25 D_s\left(\frac{a_e}{t}\right)\right] \quad \ldots 3.4.25(2)$$

for a_e/t between S_1 and S_2.

(c) $$F_s = \frac{\pi^2 E}{n_a(1.25 a_e/t)^2} \quad \ldots 3.4.25(3)$$

for a_e/t greater than S_2.

In Equations 3.4.25(1) to (3):

$$a_e = \frac{a_1}{\sqrt{1 + 0.7\left(\frac{a_1}{a_2}\right)^2}}$$

a_1 = shorter dimension of rectangular panel

a_2 = longer dimension of rectangular panel

$$S_1 = \frac{B_s - \frac{n_a F_{sy}}{n_y}}{1.25 D_s}$$

$$S_2 = \frac{C_s}{1.25}$$

SECTION 4 SPECIAL DESIGN RULES

4.1 COMBINED AXIAL LOAD AND BENDING

4.1.1 Combined compression and bending A member subjected to axial compression and bending moment loads shall be proportioned in accordance with the following two formulas (both equations must be checked):

$$\frac{f_a}{F_a} + \frac{C_{mx}\, f_{bx}}{F_{bx}(1 - f_a/F_{ex})} + \frac{C_{my}\, f_{by}}{F_{by}(1 - f_a\,/F_{ey})} \leq 1.0 \qquad \ldots 4.1.1(1)$$

$$\frac{f_a}{F_{ao}} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \leq 1.0 \qquad \ldots 4.1.1(2)$$

When $f_a/F_a \leq 0.15$, the following Equation 4.1.1(3) shall be permitted to be used in lieu of Equations 4.1.1(1) and 4.1.1(2):

$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \leq 1.0 \qquad \ldots 4.1.1(3)$$

In Equations 4.1.1(1), (2) and (3), the subscripts x and y, combined with subscripts b, m and e, indicate the axis of bending about which a particular stress or design parameter applies, and the following apply:

f_a = average compressive stress on cross-section produced by the compressive load

f_b = maximum compressive bending stress produced by the transverse loads and/or end moments

F_a = allowable compressive stress for member considered as axially loaded column according either to Clauses 3.4.8 to 3.4.11 or to Clause 4.7.2

F_b = allowable compressive stress for member considered as a beam according either to Clauses 3.4.12 to 3.4.23 or to Clause 4.7.2

C_m = $0.6 - 0.4(M_1/M_2)$ for members whose ends are prevented from swaying; or 0.85 for members whose ends are not prevented from swaying

M_1/M_2 = ratio of end moments where M_2 is the larger of the two end moments and M_1/M_2 is positive when the member is bent in reverse curvature, negative when bent in single curvature

F_{ao} = allowable compressive stress of an axially loaded member considered as a short column according to Clause 4.7.2 without consideration of Clause 3.4.8

F_e = elastic buckling stress divided by n_u

$$= \frac{\pi^2 E}{n_u (kL/r)^2}$$

r = radius of gyration about the bending axis

L = unsupported length in the plane of bending

k = effective length factor in the plane of bending

4.1.2 Combined tension and bending A member subjected to axial tension and bending shall be proportioned in accordance with the formula:

$$\frac{f_a}{F_t} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \leq 1.0 \qquad \ldots 4.1.2(1)$$

In Equation 4.1.2(1), the subscripts x and y, combined with the subscript b, indicate the axis of bending about which a particular stress or design parameter applies, and—

f_a = average tensile stress on cross section produced by the tensile load

f_b = maximum tensile bending stress produced by the transverse loads or end moments, or both

F_b = allowable tensile stress for the member considered as a beam according to Clauses 3.4.3 to 3.4.5 and 4.7.3

F_t = allowable tensile stress for the member considered loaded only axially according to Clause 3.4.2

4.2 TORSION AND SHEAR IN TUBES Allowable shear stresses in round or oval tubes due to torsion or transverse shear loads shall be determined from Clause 3.4.24 with the ratio *h/t* replaced by the equivalent *h/t* given by the following:

$$\text{Equivalent } \frac{h}{t} = 2.9 \left(\frac{R_o}{t}\right)^{5/8} \left(\frac{L_o}{R_o}\right)^{1/4} \qquad \ldots 4.2(1)$$

where

R_o = outside radius of round tube or maximum outside radius of oval tube

t = thickness of tube

L_o = length of tube between circumferential stiffeners

4.3 TORSION AND BENDING IN OPEN SHAPES The stresses in open sections caused by torsion due to twisting moments applied directly or due to lateral loads or supports not in the plane of the shear centre of open sections shall include shear, flexural and warping stresses. The stresses thus computed plus those due to bending shall not exceed the appropriate allowable stress for the type of stress in the element considered.

4.4 COMBINED SHEAR, COMPRESSION AND BENDING Allowable combinations of shear, compression and bending shall be determined from either of the following formulas:

(a) For wall of curved surfaces or round tubular members:

$$\frac{f_a}{F_a} + \frac{f_b}{F_b} + \left(\frac{f_s}{F_s}\right)^2 \leq 1.0 \qquad \ldots 4.4(1)$$

(b) For webs of rectilinear shapes, plates of built-up girders or similar members:

$$\frac{f_a}{F_a} + \left(\frac{f_b}{F_b}\right)^2 + \left(\frac{f_s}{F_s}\right)^2 \leq 1.0 \qquad \ldots 4.4(2)$$

In Equations 4.4(1) and (2):

f_a = average compressive stress produced by axial compressive load

F_a = allowable compressive stress for members subjected to compression only

f_b = maximum bending stress (compression) produced by applied bending moment

F_b = allowable bending stress (compression) for members subjected to bending only

f_s = shear stress caused by torsion or transverse shear loads

F_s = allowable shear stress for members subjected only to torsion or shear

4.5 HORIZONTAL STIFFENERS FOR WEBS If a horizontal stiffener is used on a beam web, it shall be located so that the distance from the toe of the compression flange to the centroid of the stiffener is 0.4 of the distance from the toe of the compression flange to the neutral axis of the beam. The horizontal stiffener shall have a moment of inertia, about the web of the beam, not less than that given by the expression:

$$I_h = \frac{0.02 \alpha f t h^3}{E}\left[\left(1 + \frac{6A_h}{ht}\right)\left(\frac{s}{h}\right)^2 + 0.4\right] \quad \ldots 4.5(1)$$

where

A_h = gross area of cross-section of horizontal stiffener

f = compressive stress at toe of flange

h = clear height of web between flanges

I_h = moment of inertia of the horizontal stiffener. For a stiffener consisting of equal members on both sides of the web, the moment of inertia I_h shall be the sum of the moments of inertia about the centreline of the web. For a stiffener consisting of a member on one side only, the moment of inertia shall be taken about the face of the web in contact with the stiffener

s = distance between vertical stiffeners

t = thickness of web

α = 1, for stiffener consisting of equal members on both sides of the web

α = 3.5, for stiffener consisting of member on only one side of web

4.6 VERTICAL STIFFENERS FOR SHEAR WEBS Stiffeners applied to beam webs to resist shear buckling shall have a moment of inertia not less than the value given by the following expressions:

$$\frac{s}{h} \leq 0.4, \quad I_s = \frac{0.46 n_a V h^2}{E}\left(\frac{s}{h}\right) \quad \ldots 4.6(1)$$

$$\frac{s}{h} > 0.4, \quad I_s = \frac{0.073 n_a V h^2}{E}\left(\frac{h}{s}\right) \quad \ldots 4.6(2)$$

where

h = clear height of web

I_s = moment of inertia of stiffener

n_a = factor of safety on appearance of buckling from Table 3.4(A)

s = stiffener spacing

V = shear force on web at stiffener location

When a stiffener is composed of a pair of members, one on each side of the web, the stiffener spacing *s* shall be the clear distance between the pairs of stiffeners. When a stiffener is composed of a member on one side only of the web, the stiffener spacing *s* shall be the distance between rivet lines or other connecting lines.

For a stiffener composed of members of equal size on each side of the web, the moment of inertia of the stiffener shall be computed about the centreline of the web. For a stiffener composed of a member on one side only of the web, the moment of inertia of the stiffener shall be computed about the face of the web in contact with the stiffener.

In the determination of the required moment of inertia of stiffeners, the distance *h* shall always be taken as the full clear height of the web regardless of whether or not a horizontal stiffener is present.

Stiffeners shall extend from flange to flange but need not be connected to either flange.

Unless the outer edge of a stiffener is continuously stiffened, its thickness shall not be less than 1/12th the clear width of the outstanding leg.

Vertical stiffeners shall, where possible, be placed in pairs at end bearings and at points of support of concentrated loads. They shall be connected to the web by enough rivets, or other means, to transmit the load. Such stiffeners shall be fitted to form a tight and uniform bearing against the loaded flanges, unless welds, designed to transmit the full reaction or load, are provided between flange and stiffener.

Only that part of a stiffener cross-section which lies outside the fillet of the flange angle shall be considered as effective in bearing.

The moment of inertia of the bearing stiffener shall be not less than that given by the following expression:

$$I_b = I_s + \frac{Ph^2 n_u}{\pi^2 E} \qquad \ldots 4.6(3)$$

where

E = compressive modulus of elasticity

h = clear height of web between flanges

I_b = required moment of inertia of bearing stiffener

I_s = moment of inertia required to resist shear buckling

n_u = factor of safety

P = concentrated load on stiffener

4.7 EFFECTS OF LOCAL BUCKLING ON MEMBER PERFORMANCE

4.7.1 Local buckling stresses Local buckling stress shall be calculated, using the critical stresses, F_{cr}, given in Table 4.7.1. For cases not covered in Table 4.7.1, the value of F_{cr} shall be determined using the expression for F_c in the appropriate subclause of Clause 3.4 for the case $\frac{b}{t} > S_2$ with n_u or n_y taken as 1.0.

TABLE 4.7.1

LOCAL BUCKLING STRESS

Clause	Local buckling stress, F_{cr}
3.4.9.1 and 3.4.16	$F_{cr} = \dfrac{\pi^2 E}{(5.1b/t)^2}$
3.4.10.1, 3.4.17	$F_{cr} = \dfrac{\pi^2 E}{(1.6b/t)^2}$
3.4.10.2 and 3.4.19	$F_{cr} = \dfrac{(n_y F_c)^2}{F_{cy}}$
3.4.22	$F_{cr} = \dfrac{\pi^2 E}{(0.67h/t)^2}$
3.4.23	$F_{cr} = \dfrac{\pi^2 E}{(0.29h/t)^2}$

4.7.2 Weighted average allowance compressive stress

4.7.2.1 *Compression members* The allowable compressive stress for the section as a whole shall be the weighted average allowable stress for the individual elements, where the allowable stress for each element is weighted in accordance with the ratio of the area of the element to the total area of the section.

The allowable stress in the elements being stiffened shall not exceed the allowable stress in an intermediate stiffener or an edge stiffener.

The allowable compressive stress for the section as a whole used as a column shall not exceed that given by Clause 3.4.8.

4.7.2.2 *Beams* The allowable compressive stress for a beam flange shall be the weighted average allowable compressive stress of the compression flange, where the allowable stress for each element of the compression flange is weighted in accordance with the ratio of the area of each element to the area of the compression flange.

The beam flange shall be considered to consist of the actual flange plus the flange edge or intermediate stiffener if either is present and one third of the compression portion of the web or webs.

The allowable stress in the elements being stiffened shall not exceed the allowable stress in an intermediate stiffener or an edge stiffener.

The allowable compressive stress for the section as a whole used as a beam must not exceed that given by Clause 3.4.12 or 3.4.15.

4.7.3 Weighted average allowable tensile stress The allowable tensile stress for a beam flange shall be the weighted average allowable tensile stress of the tensile flange where the allowable stress for each element of the tensile flange is weighted in accordance with the ratio of the area of each element to the area of the tensile flange.

The beam flange shall be considered to consist of the actual flange plus the flange edge or intermediate stiffener if either is present and one third of the tension portion of the web or webs.

4.7.4 Effect of local buckling on column strength An additional limitation shall be placed on the allowable stress for columns in which local buckling of the cross-section occurs at a stress that is less than the calculated flexural buckling stress of the column, assuming that the elements are not buckled. The allowable stress shall not exceed the value given by:

$$F_{rc} = \frac{(F_{ec})^{1/3}(F_{cr})^{2/3}}{n_u} \qquad \ldots 4.7.4(1)$$

$$\text{for} \quad F_{cr}/n_u < F_c \qquad \ldots 4.7.4(2)$$

where

F_c = allowable stress for column given in Clause 3.4.8

F_{cr} = element local buckling stress given in Clause 4.7.1

$$F_{ec} = \frac{\pi^2 E}{(kL/r)^2}$$

F_{rc} = allowable stress for column with buckled elements

The allowable stress also shall not exceed the allowable stress for the section given in Clause 4.7.2.

4.7.5 Effect of local buckling on beam strength The allowable compressive bending stress shall be reduced for single web beams whose flanges consist of thin, flat elements supported on one edge and in which local buckling of the cross-section occurs at a stress that is less than the lateral buckling stress of the beam, calculated assuming that the elements are not buckled. The allowable stress shall not exceed the value given by:

$$F_{rb} = \frac{(F_{ec})^{1/3}(F_{cr})^{2/3}}{n_y} \qquad \ldots 4.7.5(1)$$

$$\text{for} \quad \frac{F_{cr}}{n_y} < F_c \qquad \ldots 4.7.5(2)$$

where

F_c = allowable stress for beam given in Clause 3.4.12 or Clause 4.9

F_{cr} = element local buckling stress given in Clause 4.7.1

F_{ec} = elastic lateral buckling stress of beam calculated using Equation 3.4.12(3) and Clause 4.9 with n_y = 1.0

F_{rb} = allowable stress for beam with buckled elements

The allowable stress also shall not exceed the allowable stress for the section given in Clause 4.7.2.

4.7.6 Effective width for calculation of bending deflection Where deflection at design loads needs to be calculated, the effective width concept shall be used to determine an effective section for the moment of inertia in deflection calculations.

For sections containing elements covered in Clauses 3.4.16, 3.4.17, 3.4.22 and 3.4.23 with b/t or h/t values exceeding 1.65 S_2 and elements covered in Clauses 3.4.19 and 3.4.20 with $F_{cr} < f_a$, the effective width, b_e, of a thin element subjected to directed compression stresses is:

$$\text{If} \quad f_a \leq F_{cr}, \quad b_e = b \qquad \ldots 4.7.6(1)$$

If $f_a > F_{cr}$, $b_e = b\sqrt{F_{cr}/f_a}$ . . . 4.7.6(2)

where

b_e = effective width of flat plate element to be used in deflection calculations

b = width of element as defined in the Clauses referred to in this Clause

F_{cr} = local buckling stress for element from Clause 4.7.1

f_a = compressive stress on element due to applied loads

The same expression is used to calculate the effective width on the compression side of a web in bending, with the maximum compressive bending stress due to the applied loads, f_b, replacing f_a. In this case the effective web area is to be placed next to the compression flange.

4.7.7 Web crippling of flat webs Allowable interior reactions and concentrated loads, P_c per web for flat webs, shall be:

$$P_c = \frac{C_{wa}(N_b + C_1)}{n_y C_{wb}} \quad . . . 4.7.7(1)$$

Allowable end reactions, P_c per web for flat webs, shall be:

$$P_c = \frac{1.2C_{wa}(N_b + C_2)}{n_y C_{wb}} \quad . . . 4.7.7(2)$$

where

C_{wa} = $t^2 sin\theta(0.46F_{cy} + 0.02\sqrt{EF_{cy}})$

C_{wb} = $C_3 + R_i(1 - \cos\theta)$

C_1 = 140 mm

C_2 = 33 mm

C_3 = 10 mm

E = compressive modulus of elasticity

F_{cy} = minimum compressive yield strength of web

N_b = length of bearing at reaction or concentrated load

R_i = bend radius at juncture of flange and web measured to inside surface of bend

t = web thickness

θ = angle between plane of web and plane of bearing surface ($\theta \leq 90$ degrees)

4.7.8 Combined web crippling and bending for flat webs Allowable combinations of interior reactions and concentrated loads and bending shall be determined from the following formula:

$$\left(\frac{M}{M_a}\right)^{1.5} + \left(\frac{P_w}{P_c}\right)^{1.5} \leq 1.0 \quad . . . 4.7.8(1)$$

where

M = bending moment applied to the member

M_a = allowable bending moment for the member if bending moment alone is applied to the member

P_w = applied interior reaction or concentrated load per web for flat webs

P_c = allowable interior reaction or concentrated load per web for flat webs calculated according to Clause 4.7.7.

4.8 FATIGUE

4.8.1 General Welded details, mechanically fastened joints and base material of aluminium alloys subjected to repeated fluctuations of stress shall meet all the static requirements of this Standard as well as the fatigue requirements of this Clause. Fatigue design of castings and associated details shall be made by testing in accordance with Section 8.

There shall be no 1/3 increase in allowable stress values determined in this Clause as provided by Clause 2.3.

Categories of details for fatigue design parameters shall be chosen from Figure 4.8.1 and Table 4.8.1.

The maximum and minimum stresses used to calculate the stress range are nominal stresses determined by standard elastic methods. Stresses perpendicular to the expected plane of cracking shall be used.

4.8.2 Constant amplitude loading For constant amplitude loading:

$$S_{ra} \leq S_{rd} \quad \text{. . . 4.8.2(1)}$$

where

S_{ra} = applied stress range, the algebraic difference between the minimum and maximum calculated stress in the member or detail

S_{rd} = the allowable stress range

$$S_{rd} = KN^{-1/m} \quad \text{. . . 4.8.2(2)}$$

K, m = constants from Table 4.8.2 and shown in Figure 4.8.2

N = the number of cycles to failure

If the applied stress range, S_{ra}, is less than the constant amplitude fatigue limit as given in Table 4.8.2, then no further fatigue consideration shall be needed. The allowable stress range, S_{rd} shall not be less than the value from Equation 4.8.2(2) when $N = 5 \times 10^6$ cycles and shall not be greater than the value from Equation 4.8.2(2) when $N = 10^5$ cycles.

4.8.3 Variable amplitude loading If the maximum stress range in the spectrum is less than the fatigue limit, then no further fatigue assessment shall be needed.

For variable amplitude loading:

$$S_{re} \leq S_{rd} \quad \text{. . . 4.8.3(1)}$$

where

S_{re} = equivalent stress range

$$S_{re} = \left(\sum_{i=1}^{N_s} \alpha_i \; S_{ri}^{\,m} \right)^{\frac{1}{m}} \quad \text{. . . 4.8.3.(2)}$$

S_{rd} = the allowable stress range

$$S_{rd} = KN^{-1/m} \quad \text{. . . 4.8.3(3)}$$

α_i = number of cycles in the spectrum of the ith stress range divided by the total number of cycles

S_{ri} = the ith stress range in the spectrum

K, m = constants from Table 4.8.2 and shown in Figure 4.8.2

N_s = number of stress ranges in the spectrum

N = the number of cycles to failure

The allowable stress range S_{rd} shall not be greater than the value from Equation 4.8.3(3) when $N = 10^5$ cycles.

TABLE 4.8.1
STRESS CATEGORY

General condition	Detail	Detail category*	Fatigue design details†
Plain material	Base metal with rolled or cleaned surfaces.	A	1, 2
Built-up members	Base metal and weld metal in members, without attachments, built up of plates or shapes connected by continuous full- or partial-penetration groove welds or continuous fillet welds parallel to the direction of applied stress.	B	3, 4, 5
	Calculated flexural stress, f_b, in base metal at toe of welds on girder webs or flanges adjacent to welded transverse stiffeners.	C	6, 21
	Base metal at end of partial-length welded cover plates having square or tapered ends, with or without welds across the ends.	E	5
Mechanically fastened	Base metal at net section of mechanically fastened joints which do not induce out-of-plane bending in connected material, where		
	Stress ratio, the ratio of minimum stress to maximum stress, *SR* is:‡		
	$SR < 0$	C	7
	$O \leq SR < 0.5$	D	7
	$0.5 \leq SR$	E	7
	Base metal at net section of mechanically fastened joints which induce out-of-plane bending in connected material.	E	8
Fillet welded connections	Base metal at intermittent fillet welds.	E	
	Base metal at junction of axially loaded members with fillet welded end connections. Welds shall be disposed about the axis of the members so as to balance weld stresses.	E	15, 17
	Weld metal of continuous or intermittent longitudinal or transverse fillet welds.	F	5, 15, 18
Groove welds	Base metal and weld metal at full-penetration groove welded splices of parts of similar cross-section ground flush, with grinding in the direction of applied stress and with weld soundness established by nondestructive inspection.	B	9
	Base metal and weld metal at full-penetration groove welded splices at transitions in width or thickness, with welds ground to provide slopes no steeper than 1 to 2.5, with grinding in the direction of applied stress, and with weld soundness established by nondestructive inspection.	B	11, 12
	Base metal and weld metal at full-penetration groove welded splices, with or without transitions having slopes no greater than 1 to 2.5, when reinforcement is not removed or weld soundness is not established by nondestructive inspection.	C	9, 10, 11, 12

(*continued*)

TABLE 4.8.1 (*continued*)

General condition	Detail	Detail category*	Fatigue design details†
Attachments	Base metal detail of any length attached by groove welds subject to transverse or longitudinal loading, when the details embodies a transition radius, the radius of an attachment of the weld detail, R_t, not less than 50 mm and with the weld termination ground smooth:		
	$R_t \geq 610$ mm	B	13
	610 mm $> R_t \geq 150$ mm	C	13
	150 mm $> R_t \geq 50$ mm	D	13
	Base metal at detail attached by groove welds or fillet welds subject to longitudinal loading, with transition radius, if any, less than 50 mm:		
	50 mm $\leq a \leq 12b$ or 100 mm	D	14
	a $> 12b$ or 100 mm	E	14, 19, 20
	where a = detail dimension parallel to the direction of stress b = detail dimension normal to the direction of stress and the surface of the base metal		
	Base metal at a detail of any length attached by fillet welds or partial-penetration groove welds in the direction parallel to the stress, when the detail embodies a transition radius, R_t, not less than 50 mm and weld termination ground smooth:		
	$R_t \geq 610$ mm	B	16
	610 mm $> R_t \geq 150$ mm	C	16
	150 mm $> R_t \geq 50$ mm	D	16
	Base metal at a detail attached by groove welds or fillet welds, where the detail dimension parallel to the direction of stress, a, is less than 50 mm	C	19

* See Table 4.8.2. All stresses are T and Rev., where 'T' signifies range in tensile stress only; 'Rev.' signifies a range involving reversal of tensile or compressive stress; except Category F where stress range is in shear including shear stress reversal.

† See Figure 4.8.1. These examples are provided as guidelines and are not intended to exclude other reasonably similar situations.

‡ Tensile stresses are considered to be positive and compressive stresses are considered to be negative.

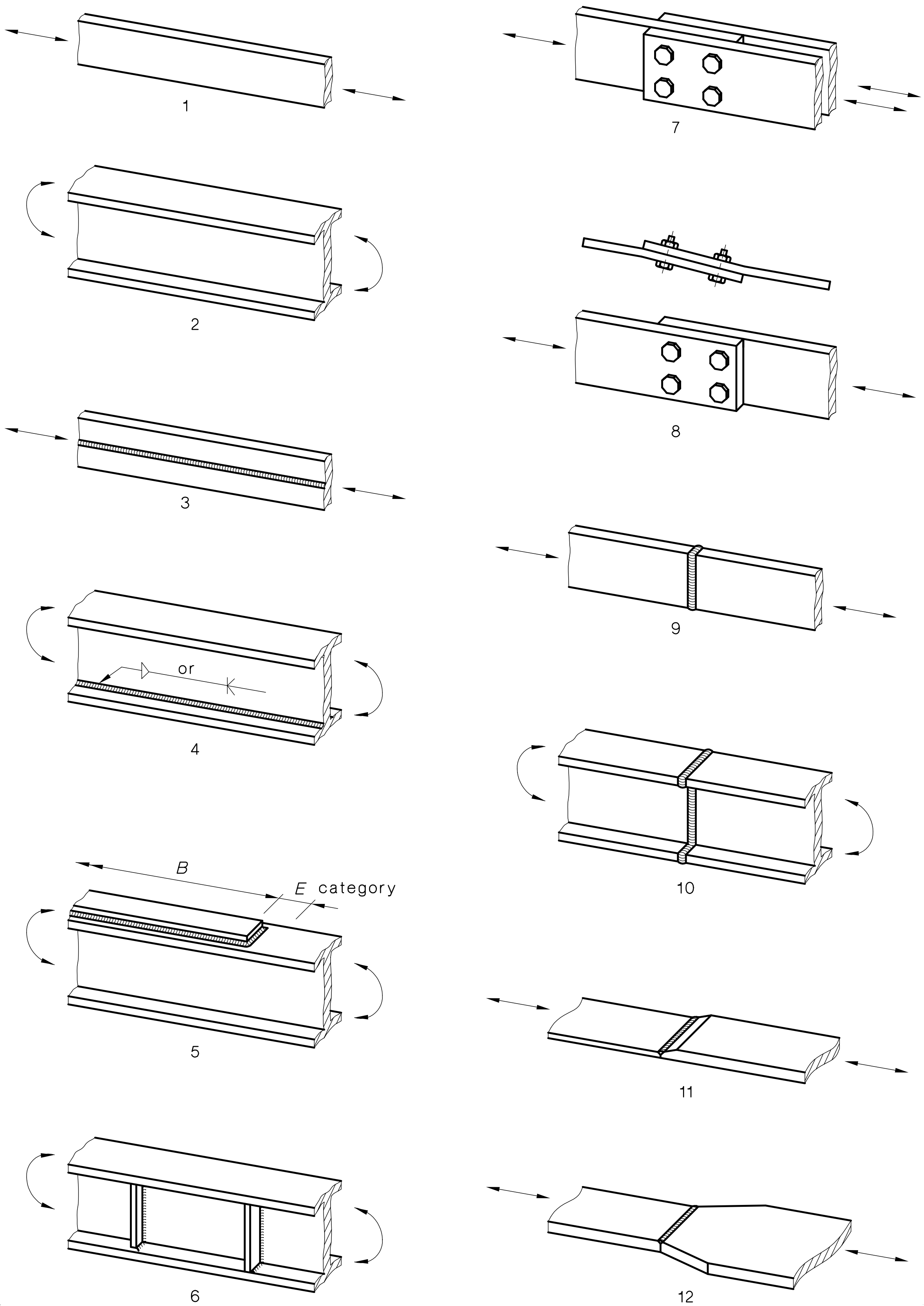


FIGURE 4.8.1 (in part) FATIGUE DESIGN DETAILS

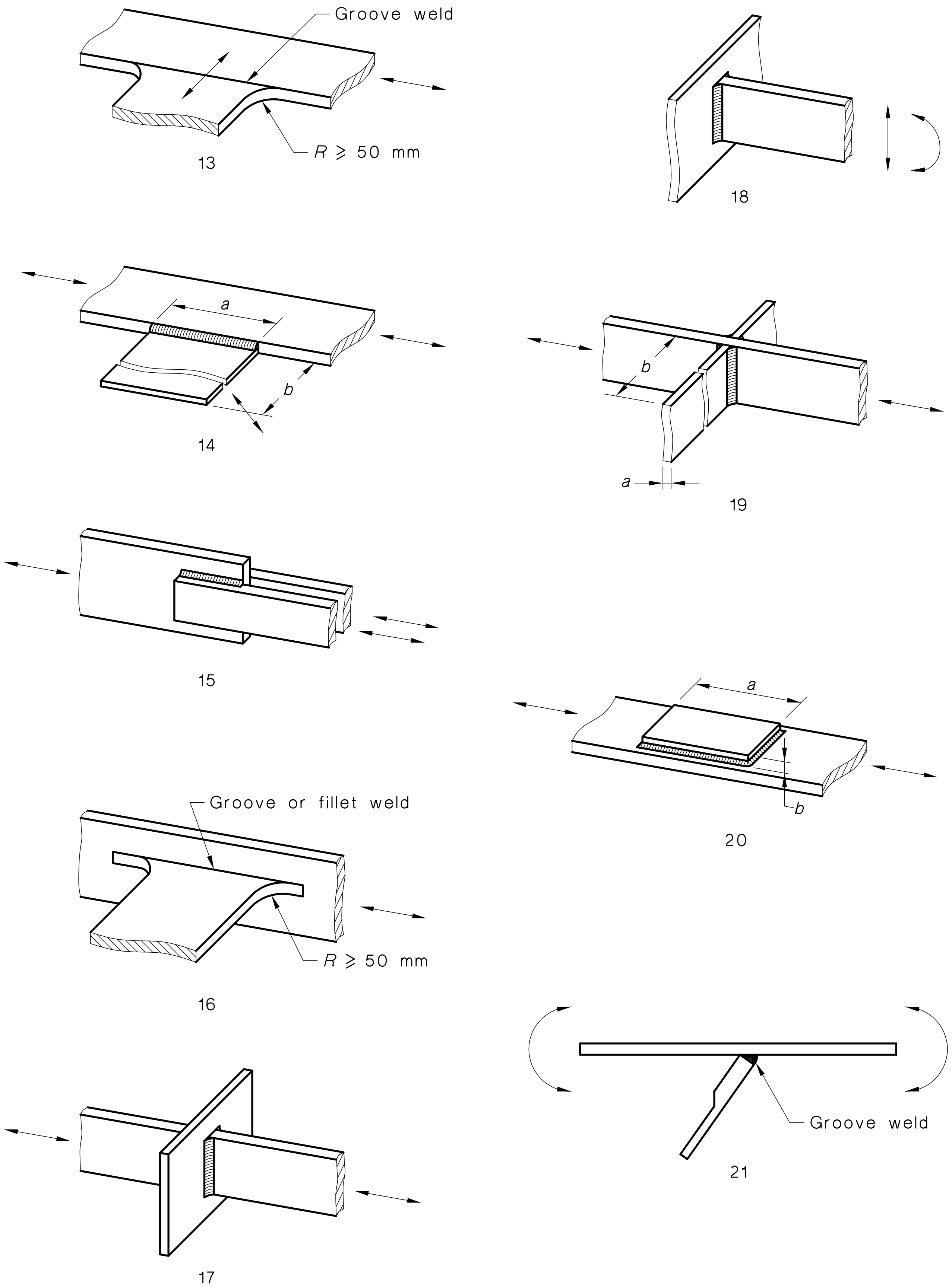


FIGURE 4.8.1 (in part) FATIGUE DESIGN DETAILS

TABLE 4.8.2

CONSTANTS FOR *S*-*N* CURVES

Detail category†	*K* MPa	*m* MPa	Fatigue limit, * S_{rd} MPa
A	665	6.85	70
B	900	4.84	37
C	1920	3.64	28
D	1080	3.73	17
E	1100	3.45	13
F	1200	3.42	13

* Fatigue limit is based on $N = 5 \times 10^6$.

† See Table 4.8.1.

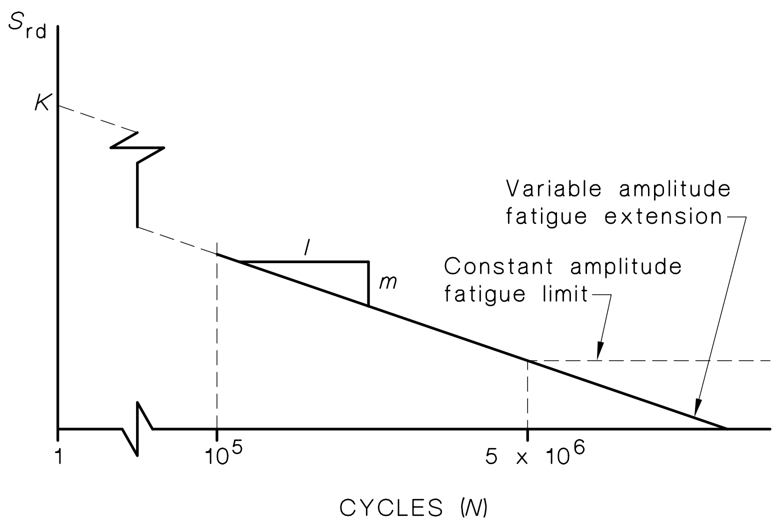


FIGURE 4.8.2 SCHEMATIC FATIGUE CURVE

4.9 COMPRESSION IN SINGLE WEB BEAMS AND BEAMS HAVING SECTIONS CONTAINING TUBULAR PORTIONS

4.9.1 General The value of r_y in Clause 3.4.12 shall be permitted to be replaced by an effective r_y denoted r_{ye} given in Clauses 4.9.2 to 4.9.4.

Sections with the tension flange partially or fully braced and with the compression flange laterally unbraced shall be permitted to be designed using a rational method of analysis.

4.9.2 Doubly symmetric sections and sections symmetric about the bending axis For checking beam sections at brace or support points or between brace or support points of beam spans subjected to end moment only or to transverse loads applied at the neutral axis of the beam, the following shall apply:

$$r_{ye} = \frac{\sqrt{C_b}}{1.7}\sqrt{\frac{I_y d}{Z_c}\sqrt{1 + 0.152\frac{J}{I_y}\left(\frac{k_y L_b}{d}\right)^2}} \qquad \ldots 4.9.2(1)$$

For checking beam spans between brace or support points of beams subjected to transverse loads applied on the top or bottom flange (where the load is free to move laterally with the beam if the beam buckles), the following shall apply:

$$r_{ye} = \frac{\sqrt{C_b}}{1.7}\sqrt{\frac{I_y d}{Z_c}\left[\pm 0.5 + \sqrt{1.25 + 0.152\frac{J}{I_y}\left(\frac{k_y L_b}{d}\right)^2}\right]} \qquad \ldots 4.9.2(2)$$

The minus sign in front of the term ‘0.5’ shall be used when the load is on a flange acting towards the shear centre; the plus sign shall be used when the load is on a flange acting away from the shear centre.

In Equations 4.9.2(1) and (2):

y-axis is the centroidal symmetry or principal axis such that the tension flange has a positive coordinate and bending is about the x-axis

C_b = bending coefficient dependent on moment gradient. The values of C_b are given in Clause 4.9.5

r_{ye} = effective radius of gyration

I_y = moment of inertia of beam about axis parallel to web

Z_c = section modulus of beam, compression side

J = torsion constant of beam. For non-tubular open sections an approximate value of J shall be calculated by assuming the section to be composed of rectangles and letting J equal the sum of the terms $bt^3/3$ for each rectangle where b is the larger dimension. The term for each rectangle whose b/t radio is less than 10 shall be computed by the expression $(1/3 - 0.2t/b)\ bt^3$

For sections containing open parts and tubular portions, J shall be taken as the sum of J for the open parts and the tubular parts

k_y = effective length coefficient for compression flange about the y-axis, k_y shall be permitted to be taken as 1.0. If k_y less than 1.0 is used then C_b shall be taken as 1.0

L_b = length of the beam between bracing points or between a brace point and the free end of a cantilever beam. Bracing points are the points at which the compression flange is restrained against lateral movement or twisting

d = depth of beam

4.9.3 Singly symmetric sections unsymmetric about the bending axis For a beam that is unsymmetrical about the bending axis, the r_{ye} in Clause 4.9.2 is calculated by taking I_y, Z_c and J as though both flanges were the same as the compression flange with the overall depth remaining the same.

4.9.4 Singly symmetric sections symmetric or unsymmetric about the bending axis, doubly symmetric sections and sections without an axis of symmetry For a loading that does not cause torsion or lateral bending a more accurate value of r_{ye} is determined according to this Clause. If the loading causes torsion and/or lateral bending, warping stress and/or lateral bending flexural stress, the provisions of Clause 4.3 shall apply.

$$r_{ye} = \frac{L_b}{1.2\pi}\sqrt{\frac{M_e}{EZ_c}} \qquad \ldots 4.9.4(1)$$

where

M_e = the elastic critical moment determined as follows:

$$M_e = C_b A F_{ey} \left[U + \sqrt{U^2 + r_o^2 \left(\frac{F_t}{F_{ey}} \right)} \right] \quad \ldots 4.9.4(2)$$

M_e for cantilever beams shall be determined by rational analysis unless the free end is braced or if the beam loading is covered in Clause 4.9.4. References for rational analysis are given in the Commentary (see AS 1664.2 Supplement 1).

In Equations 4.9.4(1) and (2):

y-axis is the centroidal symmetry or principal axis such that the tension flange has a positive y-coordinate and bending is about the x-axis

A = full cross-sectional area

C_b, C_1 and C_2 = coefficients to be taken from Clause 4.9.5, or, for cases not covered in Clause 4.9.5, determined by rational analysis

C_w = torsional warping constant of the cross-section

E = compressive modulus of elasticity (see Table 3.3(A))

$$F_{ey} = \frac{\pi^2 E}{\left(\dfrac{k_y L_b}{r_y} \right)^2}$$

$$F_t = \frac{1}{A r_o^2} \left(G J + \frac{\pi^2 E C_w}{L_t^2} \right)$$

G = shear modulus

g = distance from the shear centre to the point of application of the load. To be taken as + when the load is applied directed away from the shear centre and − when the load is directed towards the shear centre. Where there is no transverse load (pure moment cases) $g = 0$

I_y = moment of inertia of the section about the y axis

J = torsion constant (see definition in Clause 4.9.2)

$$j = \frac{1}{2I_x} \left(\int_A y^3 dA + \int_A y x^2 dA \right) - y_o \quad \ldots 4.9.4(3)$$

For doubly symmetric I sections, $j = 0$

For singly symmetric sections j shall be permitted to be approximated as

$$0.45 d_f \left(2 \frac{I_{cy}}{I_y} - 1 \right) \left[1 - \left(\frac{I_y}{I_x} \right)^2 \right] \quad \ldots 4.9.4(4)$$

In this equation I_{cy} is the moment of inertia of the compression flange taken about the y-axis, I_x and I_y are the moments of inertia of the entire section about the x- and y-axes and d_f is the distance between the flange centroids or for T-sections d_f is the distance between the flange centroid and the tip of the stem.

For singly symmetric I sections where the smaller flange is not less than 80 percent of the area of the larger flange j shall be permitted to be taken as $-y_o$

k_y = effective length coefficient for compression flange about the y-axis, k_y shall be taken as 1.0. If k_y less than 1.0 is used then C_b shall be taken as 1.0

L_t = effective length for twisting. It is taken conservatively as the unbraced length

r_o = $\sqrt{r_x^2 + r_y^2 + x_o^2 + y_o^2}$

polar radius of gyration of the cross-section about the shear centre

r_x, r_y = actual radii of gyration of the cross-section about the centroidal principal axes

Z_c = section modulus for the extreme compression fibre for bending about the x-axis

U = $C_1 g + C_2 j$ . . . 4.9.4(5)

x_o = x-coordinate of the shear centre

y_o = y-coordinate of the shear centre

4.9.5 Lateral buckling coefficients

4.9.5.1 *General* For cases not covered in Clauses 4.9.5.4 and 4.9.5.5, coefficients C_b, C_1 and C_2 shall be determined as specified in Clause 4.9.5.2 or Clause 4.9.5.3.

4.9.5.2 *Doubly symmetric sections* For doubly symmetric sections, coefficients shall be determined as follows:

C_b: $$C_b = \frac{12.5 M_{MAX}}{2.5 M_{MAX} + 3 M_A + 4 M_B + 3 M_C} \quad \text{. . . 4.9.5.2(1)}$$

where

M_{MAX} = absolute value of maximum moment in the unbraced beam segment

M_A = absolute value of moment at quarter-point of the unbraced beam segment

M_B = absolute value of moment at mid-point of the unbraced beam segment

M_C = absolute value of moment at three-quarter-point of the unbraced beam segment

C_b values for doubly symmetric section cantilever beams unbraced at the free end are given in Clause 4.9.5.5. C_b values for cantilever beams braced at the free end can be evaluated using Equation 4.9.5.2(1).

C_1: When the moments vary linearly between the ends of the unbraced segment $C_1 = 0$. For some special cases the values of C_1 are given in Clause 4.9.5.4. For other variations, unless more accurate values are available, C_1 shall be taken as 0.5.

C_2: Since $j = 0$, a value of C_2 is not needed.

4.9.5.3 *Singly symmetric sections* For singly symmetric sections, coefficient shall be determined as follows:

C_b: For sections with I_{cy}/I_y less than or equal to 0.1 or greater than or equal to 0.9 $C_b = 1.0$

For sections with I_{cy}/I_y greater than 0.1 and less than 0.9, the value of C_b shall be determined according to Equation 4.9.5.2(1).

When M_{MAX} produces compression on the larger flange and the smaller flange is also subjected to compression in the unbraced length, then the member shall be checked at the location of M_{MAX} as well as at the location where the smaller flange is subjected to its maximum compression. C_b at the location of M_{MAX} shall be calculated using Equation 4.9.5.2(1). C_b for the location where the smaller flange is subjected to its maximum compression shall be taken as 1.67.

C_1: When the moments vary linearly between the ends of the unbraced segment $C_1 = 0$. For some special cases the values of C_1 are given in Clause 4.9.5.4. For other cases C_1 shall be determined by rational analysis.

C_2: When the moments vary linearly between the ends of the unbraced segment $C_2 = 1$. For some special cases the values of C_2 are given in Clause 4.9.5.4. For other cases C_2 shall be determined by rational analysis.

4.9.5.4 *Special cases—doubly or singly symmetric sections* For simply supported beams with loadings listed as follows, the following C_b, C_1 and C_2 values shall be used, except for sections with I_{cy}/I_y less than or equal to 0.1 or greater than or equal to 0.9 where C_b shall be taken as 1.0:

(a) Uniformly distributed load over the entire span

$C_b = 1.13,\ C_1 = 0.41\ C_b,\ C_2 = 0.47\ C_b$

(b) One concentrated load placed at a distance aL from one of the ends of span

$$C_b = 1.75 - 1.6a(1 - a) \qquad \text{. . . 4.9.5.4(1)}$$

$$C_1 = \frac{C_b}{a(1 - a)\pi^2}\sin^2\pi a \qquad \text{. . . 4.9.5.4(2)}$$

$$C_2 = \frac{C_b - C_1}{2} \qquad \text{. . . 4.9.5.4(3)}$$

(c) Two concentrated loads placed symmetrically at a distance aL from each end of span

$$C_b = 1 + 2.8a^3 \qquad \text{. . . 4.9.5.4(4)}$$

$$C_1 = \frac{2C_b}{a\pi^2}\sin^2\pi a \qquad \text{. . . 4.9.5.4(5)}$$

$$C_2 = (1 - a)C_b - \frac{C_1}{2} \qquad \text{. . . 4.9.5.4.(6)}$$

4.9.5.5 *Cantilever beams* For cantilever beams braced at the support and unbraced at the free end C_b shall be taken as follows:

Concentrated load at free end applied at the centroid . . . . $C_b = 1.28,\ k_y = 1.0$

Uniform transverse load applied at the centroid . . . . $C_b = 2.08,\ k_y = 1.0$

Uniform bending moment . . . . $C_b = 0.50,\ k_y = 2.1$

4.10 COMPRESSION IN ELASTICALLY SUPPORTED FLANGES Allowable compressive stresses in elastically supported flanges, such as the compression flange of a standing seam roof or of a hat-shaped beam loaded with the two flanges in compression, shall be determined from Clause 3.4.12 with the following effective value of L_b/r_y substituted in the formulas for allowable stress:

$$\text{Effective } \frac{L_b}{r_y} = 2.7\left(\frac{E A_c^2}{\beta_s I_{yc}}\right)^{1/4} \qquad \text{. . . 4.10(1)}$$

where

A_c = area of compression element (compression flange plus 1/3 of area of web between compression flange and neutral axis)

E = compressive modulus of elasticity

I_{yc} = moment of inertia of compression element about axis parallel to vertical web

β_s = spring constant (transverse force applied to the compression flange of the member of unit length divided by the deflection due to the force)

SECTION 5 MECHANICAL CONNECTIONS

5.1 BOLTED AND RIVETED CONNECTIONS

5.1.1 General Aluminium alloys used for bolts and rivets shall be those listed in Tables 5.1.1(A) and (B). Nuts for 6.4 mm bolts and smaller shall be 2024-T4. Nuts for larger diameter bolts shall be alloy 6061-T6 or 6262-T9. Flat washers shall be Alclad 2024-T4. Spring lock washers shall be alloy 7075-T6. When specified by the designer, a minimum 0.005 mm thick anodic coating shall be applied to alloy 2024 bolts for additional corrosion resistance.

5.1.2 Allowable loads

5.1.2.1 *General* Allowable loads on fasteners that are not specified herein, shall be based on the minimum strengths for the material, alloy and hardness as in the applicable industry Standard or those recommended by the manufacturer, whichever is lower. The allowable loads shall be the smallest of the following:

(a) Values recommended by the manufacturer when available.

(b) Specified by the appropriate industry Standard when available.

(c) Determined by dividing the minimum strength for that material, alloy and hardness by the factor of safety specified in the appropriate industry Standard or that recommended by the manufacturer, whichever is larger, but in no case shall the factor of safety be less than 2.34 for buildings or 2.64 for bridges.

5.1.2.2 *Allowable tension loads* The allowable tension load on aluminium bolts shall be the root area of the aluminium bolt times the minimum tensile strength for the bolt material divided by the fastener factor of safety of 2.34 for buildings or 2.64 for bridges.

Allowable tensile stresses for aluminium fasteners are given in Tables 5.1.2.2(A) and (B).

5.1.2.3 *Allowable shear loads* The allowable shear load on aluminium rivets, screws or bolts shall be the effective shear area of the fastener times the minimum shear strength of the fastener material divided by the fastener factor of safety of 2.34 for buildings or 2.64 for bridges. Allowable shear stresses for aluminium fasteners are given in Tables 5.1.2.2(A), 5.1.2.2(B), 5.1.2.3(A) and 5.1.2.3(B).

5.1.2.4 *Allowable bearing loads* The allowable bearing load on a rivet, screw or bolt shall be the allowable bearing stress for the material being joined times the effective bearing area of the fastener. Allowable bearing stresses are specified in Tables 5.1.2.4(A) and (B). The allowable bearing stresses on bolts shall apply to either threaded or unthreaded surfaces. Minimum edge distances are given in Clauses 3.4.6 and 5.1.12.

5.1.3 Effective diameter The effective diameter of rivets shall be taken as the hole diameter, but shall not exceed the nominal diameter of the rivet by 4 percent for cold rivets and by 7 percent for hot driven rivets. The effective diameter of bolts shall be taken as the nominal diameter of bolt.

5.1.4 Shear area The effective shear area of a rivet, screw or bolt in any shear plane shall be based on the effective diameter except that for bolts with threads included in the shear plane, the effective shear area shall be based on the root diameter.

5.1.5 Bearing area The effective bearing area of rivets, screws or bolts shall be the effective diameter multiplied by the length in bearing except that for countersunk rivets and bolts, half of the depth of the countersink shall be deducted from the length.

5.1.6 Arrangements and strength of connections As far as possible connections shall be arranged so that the centre of resistance of the connection shall coincide with the resultant line of action of the load. Where eccentricity exists, members and connections shall be proportioned to take into account any eccentricities of loading at the connections.

5.1.7 Net section The net section of a screwed, riveted or bolted tension member shall be determined as the sum of the net sections of its component parts. The net section of a part is the product of the thickness of the part multiplied by its least net width. The net width for a chain of holes extending across the part in any straight or broken line shall be obtained by deducting from the gross width the sum of the diameters of all the holes in the chain and adding $s^2/4g_r$ for each gauge space in the chain. In the correction quantity $s^2/4g_r$, s denotes spacing parallel to the direction of the load (pitch) of any two successive holes in the chain, and g_r refers to gauge, the spacing perpendicular to the direction of the load of the same holes.

The net section of the part shall be obtained from that chain which gives the least net width. The hole diameter to be deducted shall be the actual hole diameter for drilled or reamed holes and the hole diameter plus 0.8 mm for punched holes.

TABLE 5.1.2.2(A)

ALLOWABLE STRESSES FOR BOLTS FOR BUILDING TYPE STRUCTURES

Alloy and temper	Minimum expected shear strength MPa	Allowable shear stress on effective area* MPa	Minimum expected tensile strength MPa	Allowable tensile stress on root area* MPa
2024-T4	255	110	427	179
6061-T6	172	76	290	124
7075-T73	283	124	469	200

* Minimum expected strength divided by 2.34.

NOTE: Values apply to either turned bolts or unfinished bolts in holes not more than 1.6 mm oversized.

TABLE 5.1.2.2(B)

ALLOWABLE STRESSES FOR BOLTS FOR BRIDGE TYPE STRUCTURES

Alloy and temper	Minimum expected shear strength MPa	Allowable shear stress on effective area* MPa	Minimum expected tensile strength MPa	Allowable tensile stress on root area* MPa
2024-T4	255	96	427	158
6061-T6	172	65	290	110
7075-T73	283	110	469	179

* Minimum expected strength divided by 2.64.

NOTE: Values apply to either turned bolts or unfinished bolts in holes not more than 1.6 mm oversized.

TABLE 5.1.2.3(A)

ALLOWABLE STRESSES FOR RIVETS FOR BUILDING TYPE STRUCTURES ALL RIVETS LISTED BELOW ARE DRIVEN COLD AS RECEIVED

Designation before driving	Minimum expected shear strength MPa	Allowable shear stress on effective area* MPa
1100-H14	65	28
2017-T4	227	96
2117-T4	179	76
5056-H32	172	72
6053-T61	138	59
6061-T6	172	72†
7050-T7	269	117

* Minimum expected shear strength divided by 2.34.

† Also applies to 6061-T6 pins.

TABLE 5.1.2.3(B)

ALLOWABLE STRESSES FOR RIVETS FOR BRIDGE TYPE STRUCTURES ALL RIVETS LISTED ARE DRIVEN COLD AS RECEIVED

Designation before driving	Minimum expected shear strength MPa	Allowable shear stress on effective area* MPa
1100-H14	65	25
2017-T4	227	86
2117-T4	179	69
5056-H32	172	65
6053-T61	138	52
6061-T6	172	65†
7050-T7	269	103

* Minimum expected shear strength divided by 2.64.

† Also applies to 6061-T6 pins.

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TABLE 5.1.2.4(A)

ALLOWABLE BEARING STRESSES FOR BUILDING TYPE STRUCTURES

Alloy and temper	Allowable bearing stress MPa	Alloy and temper	Allowable bearing stress MPa
1100-H12	76	5052-H32	165
-H14	86	-H34	186
2014-T6 sheet	365	5083-H111	158
-T651 plate	372	H116, H321 (5 to 38 mm)*	221
-T6, T6510, T6511 extrusions	338	-H116, H321 (38 to 76 mm)*	207
-T6, T651 rolled bar	365	-H323	241
Drawn tube		-H343	276
Alclad		5086-H111	145
2014-T6 sheet (up to 1 mm)*	351	-H112 (6 to 12 mm)*	131
-T6, T651 sheet plate	358	-H112 (12 to 76 mm)*	117
		-H116, H32	200
3003-H12	79	-H34	241
-H14	103		
-H16	131	5454-H111	124
-H18	145	-H112	100
		-H32	186
Alclad		-H34	207
3003-H12	76		
-H14	100	5456-H111	172
-H16	124	-H112	158
-H18	131	-H116, H321 (5 to 32 mm)*	234
		-H116, H321 (32 to 38 mm)*	221
3004-H32	152	-H116, H321 (38 to 76 mm)*	207
-H34	165		
-H36	186	6005-T5, 6105-T5	234
Alclad		6061-T5, T651 sheet & plate	241
3004-H32	145	-T6, T651, T6510, T6511	
-H34	158	Other products	234
-H14	165		
-H16	186	6063-T5 (up to 12 mm)*	110
		-T5 (over 12 mm)*	100
5005-H12	93	-T6	165
-H14	103		
-H32	83	6351-T5	234
-H34	100		
5050-H32	110		
-H34	131		

* Thicknesses are given in millimetres to which the allowable stress applies. Where not listed, bearing stress applies to all thicknesses.

NOTES:

1 The allowable bearing stresses are calculated as F_{by} from Table 3.3(A) divided by 1.65 factor of safety or F_{bu} divided by 1.2 × 1.95 = 2.34, whichever is the lesser.

2 Values are based on edge distance/fastener diameter ≥2.0.

TABLE 5.1.2.4(B)

ALLOWABLE BEARING STRESSES FOR BRIDGE TYPE STRUCTURES

Alloy and temper	Allowable bearing stress MPa
3003-H12	72
-H14	93
-H16	117
-H18	124
Alclad	
3004-H34	145
5052-H32	145
-H34	165
5083-H111	145
-H116, H321 (5 to 38 mm)*	200
-H116, H321 (38 to 76 mm)*	179
-H323	214
-H343	248
5086-H116, H32	179
5154-H38	207
5456-H111	158
-H112	145
-H116, H321 (5 to 32 mm)*	207
-H116, H321 (32 to 38 mm)*	200
-H116, H321 (38 to 76 mm)*	179
6005-T5, 6105-T5	207
6061-T6, T651 sheet & plate	214
-T6, T651, T6510 other products	207
6063-T6	152
6351-T5	207

* Thicknesses are given in millimetres to which the allowable stress applies. Where not listed, bearing stress applies to all thicknesses.

NOTES:

1 The allowable bearing streses are calculated as F_{by} from Table 3.3(A) divided by 1.85 factor of safety or F_{bu} divided by 1.2 × 2.2 = 2.64, whichever is the lesser.

2 Values are based on edge distance/fastener diameter ≥2.0.

For angles, the gross width shall be the sum of the widths of the legs less the thickness. The gauge for holes in opposite legs shall be the sum of the gauges from the back of the angles, less the thickness.

For splice members, the thickness shall be only that part of the thickness of the member that has been developed by rivets or bolts, beyond the section considered.

5.1.8 Effective sections of angles If a discontinuous angle (single or paired) in tension is connected to one side of a gusset plate, the effective net section shall be the net section of the connected leg plus one-third of the section of the outstanding leg unless the outstanding leg is connected by a lug angle. In the latter case, the effective net section shall be the entire net section of the angle. The lug angle shall be designed to develop at least one-half the total load in the member and shall be connected to the main member by at least two fasteners.

For double angles placed back-to-back and connected to both sides of a gusset plate, the effective net section shall be the net section of the connected legs plus two-thirds of the section of the outstanding legs.

For intermediate joints of continuous angles, the effective net area shall be the gross sectional area less deductions for holes.

5.1.9 Grip of rivets, screws and bolts If the grip (total thickness of metal being fastened) of rivets, screws or bolts carrying calculated stress exceeds four and one-half times the diameter, the allowable load per rivet, screw or bolt shall be reduced. The reduced allowable load shall be the normal allowable load divided by $[1/2+G_r/(9D)]$ in which G_r is the grip and D is the nominal diameter of the rivet or bolt. If the grip of the rivet exceeds six times the diameter, special care shall be taken to ensure that holes will be filled completely.

5.1.10 Spacing of rivets, screws and bolts Minimum distance between rivet centres shall be 3 times the nominal rivet diameter; minimum distance of bolt or screw centres shall be 2½ times the nominal diameter. In built-up compression members the pitch in the direction of stress shall be such that the allowable stress on the individual outside sheets and shapes, treated as columns having an effective length equal to one half the rivet, screw or bolt pitch, exceeds the calculated stress. The gauge at right angles to the direction of stress shall be such that the allowable stress in the outside sheets, calculated from Clause 3.4.10.1 exceeds the calculated stress. In this case the width b in Clause 3.4.10.1 shall be permitted to be taken as 0.8 of the gauge.

5.1.11 Spacing of stitch rivets, screws and bolts in webs Where two or more web plates are in contact, there shall be stitch rivets, screws or bolts to make them act in unison. In compression members, the pitch and gauge of such rivets or bolts shall be determined as outlined in Clause 5.1.10. In tension members, the maximum pitch or gauge of such rivets, screws or bolts shall not exceed a distance, equal to $76 + 20t$ (in millimetres) in which t is the thickness of the outside plates.

5.1.12 Edge distance of rivets, screws or bolts The minimum distance from the centre of rivet, screw or bolt under computed stress to the edge of the sheet or shape toward which the pressure is directed shall be twice the nominal diameter of the rivet, screw or bolt when using the allowable bearing stress shown in Tables 5.1.2.4(A) and (B). When a shorter edge distance is used, the allowable bearing stress shall be reduced by the ratio: actual edge distance/twice the fastener diameter (See Clause 3.4.6). The edge distance shall not be less than 1.5 times the fastener diameter to extruded, sheared, sawed, rolled or planed edges.

5.1.13 Blind rivets Blind rivets shall not be used unless the grip lengths and rivet-hole tolerance are as recommended by the respective manufacturers.

5.1.14 Hollow-end (semi-tubular) rivets If hollow-end rivets with solid cross-sections for a portion of the length are used, the strength of these rivets shall not be taken equal to the strength of solid rivets of the same material, unless the bottom of the cavity is at least 25 percent of the rivet diameter from the plane of shear, as measured toward the hollow-end, and further provided that they are used in locations where they will not be subjected to appreciable tensile stresses.

5.1.15 Steel rivets Steel rivets shall not be used in aluminium structures unless the aluminium is to be joined to steel or where corrosion resistance of the structure is not a requirement, or where the structure is to be protected against corrosion (see Clause 6.6.2).

5.1.16 Lockbolts Lockbolts shall be permitted to be used when installed in conformance with the lockbolt manufacturer's recommended practices and provided that the body diameter and bearing areas under the head and nut, or their equivalent, are not less than those of a conventional nut and bolt.

5.1.17 Steel bolts Hot-dip galvanized, electro-galvanized and aluminized steel bolts and 300 series stainless steel bolts shall be used as an alternative to aluminium bolts. Plating thickness on steel bolts must be adequate to provide corrosion protection for the anticipated environment and service life. Hot-dipped galvanized A490 bolts shall not be used. Coated steel fasteners shall be installed with a lubricant to eliminate galling and assure adequate preload.

5.2 METAL STITCHING STAPLES Allowable strength values for metal stitches in joints carrying calculated loads shall be established on the basis of tests in accordance with Section 8.

5.3 SELF TAPPING SCREW CONNECTIONS

5.3.1 Notation The following notation applies in this Clause:

C = coefficient which depends on screw location

D = nominal screw diameter

D_h = nominal hole diameter

D_w = nominal washer diameter

D_{ws} = larger of the nominal washer diameter and the screw head

F_{bu1} = bearing ultimate strength of member in contact with the screw head

F_{bu2} = bearing ultimate strength of member not in contact with the screw head

F_{by1} = bearing yield strength of member in contact with the screw head

F_{by2} = bearing yield strength of member not in contact with the screw head

F_{tu1} = tensile ultimate strength of member in contact with the screw head

F_{tu2} = tensile ultimate strength of member not in contact with the screw head

n_s = factor of safety = 3.0

P_{as} = allowable shear force per screw

P_{ns} = nominal shear strength per screw

P_{at} = allowable tensile force per screw

P_{nt} = nominal tensile strength per screw

P_{not} = pull-out force per screw

P_{nov} = pull-over force per screw

t_1 = thickness of member in contact with the screw head

t_2 = thickness of member not in contact with the screw head

All the requirements of this Clause shall apply to self-tapping screws with diameter D = 2 mm to 6.4 mm. The screws shall be thread-forming or thread-cutting, with or without a self-drilling point. Alternatively, design values for a particular application shall be permitted to be based on tests according to Section 8.

Screws shall be installed and tightened in accordance with the manufacturer's recommendations.

The tensile stress on the net section of each member joined by a screw connection shall not exceed the allowable stress from Clauses 3.4.2 to 3.4.5. The net section shall be determined according to Clause 5.1.7.

5.3.2 Shear

5.3.2.1 *General* The shear force shall not exceed the allowable bearing force for a screw according to Clause 3.4.6 nor the allowables according to this Clause.

5.3.2.2 *Connection shear* The shear force per screw shall not exceed P_{as} calculated as follows:

$$P_{as} = P_{ns}/n_s \qquad \text{. . . 5.3.2.2(1)}$$

where

P_{ns} shall be the least of

$$P_{ns} = \frac{n_s}{n_y} D F_{by1} t_1$$

$$P_{ns} = \frac{n_s}{n_y} D F_{by2} t_2$$

$$P_{ns} = \frac{n_s}{1.2 n_u} D F_{bu1} t_1$$

$$P_{ns} = \frac{n_s}{1.2 n_u} D F_{bu2} t_2$$

For $t_2/t_1 \leq 1.0$, P_{ns} shall not also exceed

$$P_{ns} = 4.2(t_2^3 D)^{½} F_{tu2} \qquad \text{. . . 5.3.2.2.(2)}$$

5.3.2.3 *Shear in screws* The ultimate shear capacity of the screw shall be determined by multiplying the allowable shear capacity determined according to Clause 5.1.2 by the factor of safety used or by test according to Section 8. The ultimate shear capacity of the screw shall not be less than 1.25 P_{ns}.

5.3.3 Tension

5.3.3.1 *General* For screws which carry tensile loads, the head of the screw or washer, if a washer is provided, shall have a diameter D_w not less than 8 mm. Washers shall be at least 1.3 mm thick.

The tension force shall not exceed P_{at} calculated as follows:

$$P_{at} = P_{nt}/N_s \qquad \text{. . . 5.3.3.1}$$

P_{nt} shall be taken as the lesser of P_{not} and P_{nov} determined in Clauses 5.3.3.2 and 5.3.3.3.

5.3.3.2 *Pull-out* The pull-out force, P_{not}, for pulling out the threaded shank of the screw through the connected plate, shall not exceed:

$$P_{not} = 0.85 t_c\, D\, F_{tu2} \qquad \text{. . . 5.3.3.2}$$

where t_c is the lesser of the depth of the penetration of screw threads in the member or sheet not in contact with the screw head not including the self-drilling point, and the thickness t_2.

5.3.3.3 *Pull-over* The pull-over force, P_{nov}, for pulling out the head of the screw through the connected plate, shall not exceed:

$$P_{nov} = Ct_1 F_{tu1} (D_{ws} - D_h) \quad \text{. . . 5.3.3.3}$$

where C is a coefficient that depends on screw location (1.0 for valley fastening and 0.7 for crown fastening), D_{ws} is the larger of the screw head diameter or the washer diameter, and shall be taken not larger than 13 mm.

5.3.3.4 *Tension in screws* The ultimate tensile capacity of the screw shall be determined by multiplying the allowable tensile capacity determined according to Clause 5.1.2 by the factor of safety used or by tests according to Section 8. The ultimate tensile capacity of the screw shall not be less than 1.25 P_{nt}.

SECTION 6 FABRICATION

6.1 LAYING OUT Laying out shall be as follows:

(a) Hole centres shall be centre punched and cutoff lines shall be punched or scribed. Centre punching and scribing shall not be used where such marks would remain on fabricated material.

(b) A temperature correction shall be applied where necessary in the layout of critical dimensions. The coefficient of expansion shall be taken as 0.000023 per degree Centigrade.

6.2 CUTTING Cutting shall be as follows:

(a) Material shall be permitted to be sheared, sawed, cut with a router, or arc cut. All edges which have been cut by the arc process shall be planed to remove edge cracks.

(b) Cut edges shall be true and smooth, and free from excessive burrs or ragged breaks.

(c) Re-entrant cuts shall be avoided wherever possible. If used, they shall be filleted by drilling prior to cutting.

(d) Oxygen cutting shall not be used on aluminium alloys.

6.3 HEATING Structural material shall not be heated, with the following exceptions:

(a) Material shall be permitted to be heated to a temperature not exceeding 200°C for a period not exceeding 30 minutes. Such heating shall be done only when proper temperature controls and supervision are provided to ensure that the limitations on temperature and time are carefully observed. If structural material is subjected to elevated temperatures or times in excess of the foregoing, the allowable stresses shall be reduced consistent with mechanical properties specified for the material after the heating process.

For 5XXX series alloys with magnesium contents greater than 3 percent, holding within the temperature range from 66°C to 230°C must be avoided in order to minimize the risk of creating a stress corrosion sensitive metallurgical structure. The length of time at temperature is a critical factor in determining the degree of sensitization. Hot forming techniques must include quick heat up to a temperature not to exceed 290°C to minimize loss of mechanical properties. Forming must be completed before the metal cools below 230°C. The metal shall then be fan cooled, to drop the metal temperature from 230°C to 66°C in the minimum time possible to prevent sensitization.

Some elevated temperature processes, such as factory paint curing or firing of porcelain enamel coatings, can reduce the mechanical properties of the metal. Since the amount of the reduction will vary with the alloy and temper used, as well as with the elevated temperature exposure, the supplier shall be consulted for mechanical property specifications for the processed material.

6.4 PUNCHING, DRILLING AND REAMING The following rules for punching, drilling, and reaming shall be observed:

(a) Rivet or bolt holes shall be permitted to be either punched or drilled. Punching shall not be used if the metal thickness is greater than the diameter of the hole. The amount by which the diameter of a sub-punched hole is less than that of the finished hole shall be at least 1/4 the thickness of the piece and in no case less than 0.8 mm.

(b) The finished diameter of holes for cold-driven rivets shall be not more than 4 percent greater than the nominal diameter of the rivet.

(c) The finished diameter of holes for hot-driven rivets shall be not more than 7 percent greater than the nominal diameter of the rivet.

(d) The finished diameter of holes for bolts shall be not more than 1.6 mm larger than the nominal bolt diameter.

(e) If any holes must be enlarged to admit the rivets or bolts, they shall be reamed. Poor matching of holes shall be cause for rejection. Holes shall not be drilled in such a manner as to distort the metal. All chips lodged between contacting surfaces shall be removed before assembly.

6.5 RIVETING

6.5.1 Driven head The driven head of aluminium alloy rivets shall be of the flat or the cone-point type, with dimensions as follows:

(a) Flat heads shall have a diameter not less than 1.4 times the nominal rivet diameter and a height not less than 0.4 times the nominal rivet diameter.

(b) Cone-point heads shall have a diameter not less than 1.4 times the nominal rivet diameter and a height to the apex of the cone not less than 0.65 times the nominal rivet diameter. The included angle at the apex of the cone shall be approximately 127°.

6.5.2 Hole filling Rivets shall fill the holes completely. Rivet heads shall be concentric with the rivet holes and shall be in proper contact with the surface of the metal.

6.5.3 Defective rivets Defective rivets shall be removed by drilling.

6.6 PAINTING

6.6.1 General Structures of the alloys covered by these specifications are not ordinarily painted (with the exception of the 2000 series alloys when exposed to corrosive environments). Surfaces shall be painted where the following apply:

(a) The aluminium alloy parts are in contact with, or are fastened to, steel members or other dissimilar materials.

(b) The structures are to be exposed to extremely corrosive conditions, or for reason of appearance.

Painting procedure is covered in Clauses 6.6.2 and 6.6.3, and methods of cleaning and preparation are given in Clause 6.7.

6.6.2 Contact with dissimilar materials Where the aluminium alloy parts are in contact with, or are fastened to, steel members or other dissimilar materials, the aluminium shall be kept from direct contact with the steel or other dissimilar material by painting as follows:

(a) Steel surfaces to be placed in contact with aluminium shall be painted with good quality non-lead-containing priming paint, such as zinc molybdate, alkyd type primer, followed by two coats of paint consisting of 200 g. of aluminium paste pigment (ASTM D 962, Type 2, Class B) per litre of varnish. Where severe corrosion conditions are expected, additional protection can be obtained by applying a suitable sealant to the faying surfaces, capable of excluding moisture from the joint during prolonged service in addition to the zinc molybdate, alkyd type primer. Aluminized, hot-dip galvanized or electro-galvanized steel placed in contact with aluminium need not be painted. Stainless steel (300 series) placed in contact with aluminium need not be painted except in high chloride containing environments.

(b) Aluminium shall not be placed in direct contact with wood, fibreboard or other porous material that absorbs water and causes corrosion. When such contacts cannot be avoided, an insulating barrier between the aluminium and the porous material shall be installed. Aluminium surfaces shall be given a heavy coat of alkali resistant bituminous paint or other coating providing equivalent protection before installation. Aluminium in contact with concrete or masonry shall be similarly protected in cases where moisture is present and corrosives will be entrapped between the surfaces.

(c) Aluminium surfaces to be embedded in concrete ordinarily need not be painted, unless corrosive components are added to the concrete or unless the assembly is subjected for extended periods to extremely corrosive conditions. In such cases, aluminium surfaces shall be given one coat of suitable quality paint, such as zinc molybdate primer or a heavy coating of alkali resistant bituminous paint, or shall be wrapped with a suitable plastic tape applied in such a manner as to provide adequate protection at the overlaps. Aluminium shall not be embedded in concrete to which corrosive components such as chlorides have been added if the aluminium will be electrically connected to steel.

(d) Water that comes in contact with aluminium after first running over a heavy metal such as copper may contain trace quantities of the dissimilar metal or its corrosion product, which will cause corrosion of the aluminium. Protection shall be obtained by painting or plastic coating the dissimilar metal or by designing the structure so that the drainage from the dissimilar metal is diverted away from the aluminium.

(e) Prepainted aluminium generally does not need additional painting even in contact with other materials such as wood, concrete or steel. Under extremely corrosive conditions, additional protection shall be provided as described in the preceding paragraphs.

6.6.3 Over-all painting Structures of the alloys covered by these specifications are either not ordinarily painted for surface protection (with the exception of the 2000 series alloys when exposed to corrosive environments) or are made of prepainted aluminium components.

NOTE: For applications where the structures are to be exposed to extremely corrosive conditions over-all painting may be specified.

6.7 CLEANING AND TREATMENT OF METAL SURFACES Prior to field painting of structures, all surfaces to be painted shall be cleaned immediately before painting, by a method that will remove all dirt, oil, grease, chips, and other foreign substances.

Exposed metal surfaces shall be cleaned with a suitable chemical cleaner such as a solution of phosphoric acid and organic solvents. Abrasion-blasting shall not be used on aluminium less than or equal to 3 mm thick.

SECTION 7 WELDED CONSTRUCTION

7.1 ALLOWABLE STRESSES FOR WELDED MEMBERS Allowable stresses for welded members shall be determined from the same formulas that are used for nonwelded members. These formulas are given in Table 3.4(C). The buckling formulas for nonwelded members apply only to those cases in which welds are at the supports of beams and columns, and at the edge of plates. In applying these formulas to welded structures, the maximum strengths are limited to those given in Table 3.3(B). An exception is the case of welded tubes (Clauses 3.4.11, 3.4.13 and 3.4.18), for which the buckling coefficients are determined from the formulas in Table 3.3(C), using the 250 mm gauge length compressive strength F_{cyw} from Table 3.3(B).

For alloy 6005 up through 6 mm thick which are welded in the -T1 temper with filler alloy 4043 and precipitation heat treated (artificially aged) to the -T5 temper, by an approved method after welding, the allowable stresses within 25 mm of the weld shall be 85 percent of the values for nonwelded alloy 6005-T5.

For alloy 6063 up through 10 mm thick, which are welded in the -T4 temper with filler alloy 4043 and precipitation heat treated (artificially aged) to the -T6 temper, by an approved method after welding, the allowable stresses within 25 mm of the weld shall be 85 percent of the values for nonwelded alloy 6063-T6.

7.2 FILLER WIRE The choice of filler metal for general purpose welding shall be those alloys listed in AS 1665; the allowable shear stresses in fillet welds shall be those listed in Tables 7.2(A) and 7.2(B).

For filler wires not shown on Tables 7.2(A) and 7.2(B) minimum mechanical properties shall be determined by test in accordance with Section 8.

7.3 MEMBERS WITH LONGITUDINAL WELDS If less than 15 percent of the area of a given member cross-section or beam flange lies within 25 mm of a weld, regardless of material thickness, the effect of welding may be neglected and allowable stresses calculated as outlined in Section 3. If A_w is equal to or greater than 15 percent of A the allowable stress shall be calculated from:

$$F_{pw} = F_n - \frac{A_w}{A}(F_n - F_w) \qquad \ldots 7.3$$

where

F_{pw} = allowable stress on cross-section, part of whose area lies within 25 mm of a weld

F_n = allowable stress for cross-section 25 mm or more from weld

F_w = allowable stress on cross-section if entire area were to lie within 25 mm of weld. Strengths across a groove weld shall be as given in Table 3.3(B). For yield strengths (F_{tyw}, F_{cyw}) the allowable stress is based upon a calculated yield strength equal to 0.75 times the as-welded strength given in Table 3.3(B).

A_w = the portion of area of cross-section A lying within 25 mm of a weld.

A = net area of cross-section of a tension member or tension flange of a beam, or gross area of cross-section of a compression member or compression flange of a beam. A beam flange is considered to consist of that portion of the member further than $2c/3$ from the neutral axis, where c is the distance from the neutral axis to the extreme fibre

The column buckling formulas for the reduced strength material are calculated using the buckling coefficients given in Table 3.3(C) regardless of alloy and temper.

7.4 MEMBERS WITH TRANSVERSE WELDS The allowable stresses in Section 3 apply to members supported at both ends with welds at the ends only (not farther than 0.05 *L* from the supports).

For columns and beams with transverse welds at locations other than the supports, and/or cantilever columns and cantilever beams with transverse welds at or near the supported ends, the strength shall be calculated assuming that the entire column or beam has a yield strength F_{cyw}, as given in Table 3.3(B). The buckling coefficients given in Table 3.3(C) shall be used to develop the buckling formulas.

7.5 WELDING FABRICATION All welding shall be done in accordance with AS 1665.

TABLE 7.2(A)

ALLOWABLE SHEAR STRESSES IN FILLET WELDS FOR BUILDING TYPE STRUCTURES—MPa

Filler alloy‡	1100	4043	5183	5356 5554	5556	5654
Parent alloy	**Shear stress MPa**					
1100	22	33†	—	—	—	—
3003	22	34	—	—	—	—
Alclad 3004	—	34	55	48	55†	—
5052	—	34	55	48	59	34
5083	—	—	55	48	59	—
5086	—	—	55	48	59	—
5154	—	—	55	48	59	34
5454	—	34	55	48	59	—
5456	—	—	55	48	59	—
6005, 6061, 6351	—	34	55	48	59	—
6063	—	34*	45†	45†	45†	—

NOTE: Shear stress is considered to be equal to the load divided by the throat area.

TABLE 7.2(B)

ALLOWABLE SHEAR STRESSES IN FILLET WELDS* FOR BRIDGE TYPE STRUCTURES—MPa

Filler alloy‡	1100	4043	5183	5356 5554	5556	5654
Parent alloy	**Shear stress MPa**					
3003	19	30	—	—	—	—
Alclad 3004	—	30	48	45	48†	—
5052	—	30	48	45	52	31
5083	—	—	48	45	52	—
5086	—	—	48	45	52	—
5154	—	—	48	45	52	31
5454	—	30	48	45	52	—
5456	—	—	48	45	52	—
6005, 6061, 6351	—	30	48	45	52	31
6063	—	30	41†	41†	41†	31

* 55 MPa for welds joining round or oval members subject to bending and loading transversely in socket type base assemblies for alloy 6063 lighting poles through 10 mm wall thickness, when welded in T4 temper and artificially aged to T6 temper following welding. 41 MPa for lighting pole 6063 tubular joints other than socket type.

† Values controlled by the shear strength of the parent metal.

‡ Minimum expected shear strengths of filler alloys are:

Alloy	Shear strength, in MPa
1100	52
4043	79
5183	127
5356	117

Alloy	Shear strength, in MPa
5554	117
5556	138
5654	83

NOTE: Shear stress is considered to be equal to the load divided by the throat area.

SECTION 8 TESTING

8.1 SCOPE AND GENERAL

8.1.1 General Testing is an acceptable method for substantiating the design of aluminium alloy load carrying structures, members, or connections, whose strengths cannot otherwise be determined in accordance with Sections 1 to 7 of this Standard.

8.1.2 Scope of Section The method of test given in this Section is applicable to complete structures, sub-structures, and individual members of connections. Other Standards are referred to for the determination of material properties, and for testing of specific structural assemblies. The method of this Section is not applicable to the testing of structural models, nor to the establishment of general design data.

8.2 TEST REQUIREMENTS The actual in-service conditions shall be simulated as closely as possible in the construction of the test specimens, their support during testing, and the application of the test loads.

Loading devices and data acquisition equipment shall be calibrated, and no artificial restraints shall be applied by the loading systems.

The test load shall be determined in accordance with Clause 8.4.

A preload, equal to the long-term serviceability design load, shall be applied to the specimen for a period of 1 minute, and then removed. The test load shall then be applied to the specimen at a rate as uniform as practicable.

Deformations shall, as a minimum requirement, be recorded at the following times:

(a) Prior to the application of the test load.

(b) After the test load has been applied.

(c) After the removal of the test load.

Sufficient additional readings shall be made to enable a plot of a load/deformation curve to be made.

8.3 TESTS FOR DETERMINING MATERIAL PROPERTIES Material properties for alloys and products not included in Tables 3.3(A) and 3.3.(B) may be established by tests carried out in accordance with AS 1391.

8.4 PROCEDURE

8.4.1 Application This Clause applies to the testing of a structure, sub-structure, member or connection to determine whether that particular element complies with the requirements for strength or deflection as appropriate.

8.4.2 Test load The test load shall be equal to the permissible load as determined from Clause 2.3, multiplied by 2 for dead and live loads, 1.5 for combination of loading including wind and 2.6 where the stresses are produced entirely by wind.

8.4.3 Criteria for acceptance Criteria for acceptance shall be as follows:

(a) *Acceptance for strength* The test structure, sub-structure, member or connection shall be deemed to comply with the requirements for strength if it is able to sustain the test load for at least 15 minutes. It shall than be inspected to determine the nature and extent of any damage incurred during the test. The effects of the damage shall be considered and, if necessary, appropriate repairs to the designed parts carried out.

(b) *Acceptance for serviceability* The maximum deformation of the structure or member under the permissible load shall be within the serviceability limits appropriate to the structure.

8.5 REPORTING OF TEST RESULTS The report of the test on each specimen shall contain the following:

(a) The test results.

(b) A statement of the conditions of testing, including the method of loading and of measuring deflection.

(c) Any other relevant data.

(d) A statement as to whether or not the structure or part tested satisfied the acceptance criteria.

(e) Reference to this Australian/New Zealand Standard, i.e. AS/NZS 1664.1.

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